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THE DEVELOPMENT OF ARMOR FOR NAVAL USE.

BY

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I.

PROJECTILE ENERGY AND ARMOR RESISTANCE.

The introduction of armor as an element of naval warfare was the direct result of the increase in power of artillery beyond the capability of wooden walls for protection to men and material; and the *development* of armor is a direct sequence of the development of artillery. No description of armor experiments can, therefore, be rendered thoroughly intelligible, nor can discussions with regard to armor be intelligently carried on, without first having a clear idea of the artillery power, upon which its existence and development depend.

Since it is the especial object of armor to give protection against the effects of projectiles, the true definition of "artillery power," as the term is used in discussions with regard to armor, is: That power of projectiles which tends to overcome the resistance offered by armor. When a gun is fired, the projectile leaves the muzzle possessing a certain power—that is, it will do a certain amount of work in coming to rest. No matter how or under what circumstances the projectile is brought to rest, it will always have done an amount of work exactly equivalent to the power imparted to it by the explosion of the charge of powder. This power, possessed by the projectile just

as it leaves the gun, is called muzzle energy. In order that the mind may be capable of estimating its amount and its relation to other forces, a unit of measurement is given it, called the "foot-ton," which is the amount of work required to raise a ton weight one foot high. The expression for any number of these units, in mathematical language, is $E=\frac{W}{2g}V^2$, in which E is the energy in foot-tons, W is the weight of the projectile in the fraction of a ton, g is the force of gravity, and V is the velocity in feet. Wherever, therefore, the weight of a projectile is known and the velocity with which it is moving, the amount of energy that it contains or the work that it will do may be estimated.

When the projectile moves from the muzzle of the gun it commences to do work, or use its energy in overcoming the obstacles to its flight. In tracing this dissipation of energy of a projectile when it attacks armor, it will be conducive to clearness to divide it into three distinct parts: 1. The wasted energy, or that which is used in doing work elsewhere than on the armor and the objects which the armor protects; 2. The useful energy, or that which is actually transferred to the armor and overcomes its resistance; 3. The surplus energy, or that which remains after the armor is overcome, to do damage to the objects protected. In passing from the gun to the armor, a certain amount of energy is wasted in overcoming the resistance of the air to the projectile in flight. On striking the armor, if the projectile becomes deformed by the impact, that deformation represents more wasted energy. If it is broken in pieces, the act of breaking measures another loss; in the latter case, any change in the direction of the flight of the pieces wastes still more energy; while if the pieces are thrown back from the armor, all the energy which they have left is wasted.

The tendency of a projectile when it strikes armor is to keep on in its original direction or penetrate. If it penetrates at all, that penetration represents a certain amount of *useful* energy. The act of penetration creates a disturbance in the particles of the armor immediately surrounding the place struck, which disturbance spreads in waves of vibration like the disturbance-waves caused by a body striking a still-water surface. If this disturbance is sufficient to either wholly or partially overcome the cohesion of the particles, the resulting cracks or distortions represent another factor of useful energy. (In using the term armor, unless special designation is made, it will be understood that not only the actual metal plates are meant, but also the backing,

fastenings, and all other supports not forming an integral part of the frame of the vessel; therefore the crushing and piercing of backing and shearing or snapping of bolts represent factors of useful energy.)

If the energy transferred from the projectile to the armor be sufficient to cause any part of it to affect the objects protected, the movement causing injurious effects is a measure of *surplus* energy. All the remaining energy left in a projectile, or in parts of it, after passing through armor, is also surplus. In estimating the *value* of surplus energy, the effectiveness of its distribution is a most important element. An energy that is barely sufficient to kill one man may, if properly distributed, disable a dozen, or that which would break a single piston-rod might disable two or more engines.

If, in any armor experiment, all these factors of energy be summed up, the total will be exactly equal to the muzzle energy; and it follows, as a corollary to this assertion, that, knowing the amount of muzzle energy, the factors may be deduced from observation of the effects; and, when classified, and the laws of their variation are known, the relative value of armor-guns and of different types and dispositions of armor may be closely estimated.

The first step necessary in the investigation of the value of the various factors, is to present to the mind by means of figures a tangible idea of the magnitude of muzzle energy necessary to overcome armor. In establishing this magnitude it is well to start at the point where artillerists had so developed it as to render imperative the introduction of armor. The naval guns used in all the first armor experiments of importance were the 32 pdr. and 68 pdr. smoothbore, or other guns approximating very closely to these in power. The 32 pdr., with a powder charge of ten pounds and a projectile of 32 lbs., gave a muzzle energy of about 650 foot-tons. The 68 pdr., with a powder charge of sixteen pounds and a projectile of 66 lbs., gave a muzzle energy of about 1150 foot-tons. It may therefore be assumed without much error, that the existence of muzzle energies of from 500 to 1000 foot-tons caused the introduction of armor.

Since the period of the first introduction of armor, artillery has developed from the 68 pdr. smoothbore to the 2000 pdr. (100 ton) rifle, whose muzzle energy averages about 35,000 foot-tons; that is, the heaviest projectile used afloat to-day will do about thirty times as much work as the heaviest projectile used in ships' batteries forty years ago. This small increase of power will, no doubt, appear surprising to many who have accustomed themselves to the loose asser-

tion that the heavy guns of to-day are immeasurably more powerful than those of old times. It is true, nevertheless; and, as will be shown, the immeasurable superiority of the present guns is due, not to any great increase of original energy, but to a wiser disposition of it. The following list of guns, with the muzzle energies of their projectiles, will prove useful to those who wish to accustom themselves to the consideration of these original magnitudes.

	32	pdr. shell gun,	467 foot-tons.
	32	pdr. shot gun,	642
	68	pdr. shot gun,	1145
	10	inch shell gun,	1025
	15	inch cored shot,	7273
Old type	40	pdr. Armstrong rifle,	386
" "	120	pdr. Armstrong rifle,	1207
	10	inch Woolwich rifle,	5165
	100	ton Armstrong rifle,	35094
	10½	inch Armstrong wire rifle,	12750

In order that a projectile should overcome armor, it must be brought in contact with it, and the act of transportation from the muzzle to the armor requires an expenditure of work which has been classed as waste energy, and its amount must be known, so that an idea may be obtained of the "striking energy," or that which actually attacks the armor. It is not the province of this article to investigate the laws of the resistance of air, but from the following table, which gives the percentage of energy lost by projectiles from the guns above mentioned in traversing different ranges within good fighting distance for men-of-war, an idea may be formed of the importance of this source of waste.

Gun.	Percentage of Energy lost in a Range of			
	30 Yards.	300 Yards.	600 Yards.	1200 Yards.
32 pdr., 10 lb. charge	4.3	35.5	56.8	76.0
68 pdr., 16 lb. charge	3.8	30.5	48.4	68.4
15 inch, 100 lb. charge	1.8	16.0	29.2	38.1
40 pdr. rifle, 5 lb. charge	1.2	11.3	20.1	31.4
210 pdr. rifle, 18 lb. charge	0.8	8.2	15.3	25.6
10 inch Woolwich, 70 lb. charge	0.7	6.0	11.6	21.5
10½ inch Armstrong, 250 lb. charge	0.6	5.4	10.7	20.4
100 tons Armstrong, 440 lb. charge	0.3	3.6	7.0	14.0

It is very often the custom, in comparing the powers of different guns, to leave entirely out of consideration the effect of the resistance of the air on projectiles, under the supposition that for moderate ranges it is not of any importance. This table shows at a glance how serious a matter this factor of waste energy is. The old 32 pdr. lost in this way more than half its power in a range of 600 yards, or in less than two seconds from the time it left the gun. The 100 ton projectile in a range of 1200 yards loses more energy than the 10 inch Woolwich projectile possesses at the muzzle. The great advantage that the artillerist has secured in economizing this waste energy is strikingly shown in comparing the 100 ton gun with the old 68 pdr., as was done before. It will be found that the energy of the heavy projectile at 1200 yards is more than 83 times that of the light one, instead of 30 times, as it was at the muzzle. Or, again, comparing the 15 inch spherical projectile and the 10¼ inch rifle projectile, both of which weigh 450 lbs. The latter at the muzzle has about 57 per cent. greater energy, while at 1200 yards it has more than 100 per cent. greater. Again, the 68 pdr. fired 16 lbs. of powder and the old 128 pdr. 18 lbs., which would develop, roughly, 10 per cent. more power. At 600 yards, which was considered good fighting range for the 68 pdr., nearly one-half of the power was gone, while the 120 pdr. had only lost less than one-sixth of its energy.

The next factor of wasted energy is that due to the deformation or breaking up of the projectile, and the first point to be investigated is as to whether armor will cause this effect. To ascertain this point it is necessary to examine the records of experiments. In 1854 experiments were carried on in Portsmouth, England, with cast-iron projectiles of various calibres up to the 68 pdr., and the official report states that both solid and hollow projectiles would pass through ⅜ inch iron without breaking; that hollow shot would break in passing through ½ inch plates, but solid ones would not, and that solid shot would break in passing through ⅝ inch. This result was verified in 1863. Records of experiments carried on in the United States show that 11 inch solid cast-iron shot would break up in passing through 3 inch plates, and 15 inch shot would break against 4½ inch plates. Experiments in England and the United States showed that 68 pdr. wrought-iron shot would be deformed, so as to have an elongated diameter of 10 inches instead of 8 inches; 10½ inch shot elongated to 13 inches, and 15 inch shot to 17 inches. In an official report of Woolwich experiments in 1856 of the 68 pdr. against 4 inch plates, it

is stated that the cast-iron shot broke up into small fragments on striking and spread right and left from 100 to 150 yards and about 50 yards back. The wrought-iron shot did not break, but recoiled a few yards. In another report of that date the following sentence occurs: "The effect of wrought-iron shot at 600 yards over cast-iron shot appears to be in the proportion of 3 to 1."

From the last quotation it would seem that fully two-thirds of the energy of cast-iron projectiles might be wasted on account of the liability to break up, the pieces being thrown off from the face of the armor and their energy wasted; but it would hardly do to accept such a rough estimate, unsupported by more reliable evidence. This evidence is available, however, and is furnished from experiments made to determine this particular point by Fairbairn, whose name, associated with scientific investigation, is sufficient to establish the truth of the test. In 1862, whilst a member of a special committee engaged in experiments on armor, he made an official report, in which, after giving the full details of experiments on punching with different metals, he states "that cast iron is inferior to wrought iron and steel in its dynamic effect, or work done in crushing, in the ratio of about 1 to 3 for steel and 1 to 2.6 for wrought iron." From this, and assuming that the steel specimens with which Fairbairn worked were perfectly rigid, which approximates closely to the truth, it may be assumed that where the full power of projectiles is called into play the cast-iron one wastes 66 per cent. of its energy by breaking up, and the wrought-iron one 14 per cent. by deformation. Here, again, is seen the great importance to the artillerist of saving waste energy by choosing well the metal of his projectile.

As an example of the actual magnitude of the waste energy, suppose a 68 pdr. cast-iron shot to be fired against a 4½ inch plate at 600 yards. Starting with a muzzle energy of 1145 foot-tons, it loses 48.4 per cent. in going from the gun to the target, so that its striking energy is reduced to 591 foot-tons. In its attempt to pierce or break down the armor it is broken up itself and the pieces are reflected, causing a loss of 66 per cent. of the striking energy, so that of the original 1145 foot-tons but 195 will have performed actual work on the armor. In comparison with this loss, take the old Armstrong 120 pdr. projectile—supposing it to be of tempered steel. The muzzle energy is 1200 foot-tons, the striking energy at 600 yards is 1064, and since the projectile neither breaks nor deforms, all of this energy does work upon the armor—or, in other words, the comparative effective-

ness at the muzzle of the 68 pdr. smoothbore and the 120 pdr. rifle being as 1 to 1.05, is at 600 yards, through the saving of waste energy, as 1 to $5\frac{1}{2}$ nearly.

Thus far in the investigation the artillery side of the subject has been alone considered, as it is beyond the province of the armor manufacturer to control either the amount of muzzle energy given to the projectile, or the amount of waste energy created by reason of the form or material of the shot. In the distribution of the useful and surplus energies lies the ground of conflict between guns and armor. As has been before explained, useful energy is expended in accomplishing two distinct objects; namely, piercing the armor and racking it. Both of these effects are apparent in all cases of impact of projectiles against armor; but it is within the power of the artillerist to so divide these effects as to throw the main part of the energy into either penetrating or racking, as he chooses; and (what should not be lost sight of) it is equally in the power of the armor manufacturer to so constitute his armor as to give it special powers of *resisting* the one or the other effect.

This possibility of developing artillery power, so as to throw the main stress or useful energy either in the direction of punching or racking, gave rise at an early period of armor experiment to much discussion as to the true line of development, and since but one of the two lines of development could be the true one, the subject merited the most careful investigation. A thorough understanding of this point is fully as important now as it was then, especially to naval officers, who have both the artillery and the armor to deal with. The bases of the arguments may be stated as follows:

1st. Those in favor of punching held that the most feasible method of attack was to waste no power in racking the whole side of a ship, but to devote the power exclusively to punching the armor—with shells, if possible.

2d. Those in favor of racking held it to be the better method to waste no time in punching mere holes, but to so increase the weight of the shot (reducing the velocity correspondingly, so as not to overstrain the gun) that the entire blow shall be expended in straining, loosening, and dislocating the armor and breaking its fastenings, thus tearing it off, after which the vessel will be easily destroyed by shells.

A very erroneous idea was for a long time prevalent amongst those who were not experts, and it still exists even in text-books, with regard to the manner in which artillerists treated the subject—it being

asserted that punching was produced with *light* projectiles having *high* velocities, and racking with *heavy* projectiles having *low* velocities. Such effects will be produced under certain circumstances with these conditions; but, starting from such an indefinite basis, the mind is quickly led off into erroneous speculations. As a case in point, it will be found that, as a rule, this basis is illustrated by the familiar experiment of firing a bullet through a pane of glass and punching a small hole, while by throwing a large pebble the whole pane is smashed. This is true as regards the substance glass, whose qualities cannot be modified by ordinary processes. If, however, a sheet of sole-leather be substituted for the pane of glass, the illustration falls to the ground. As a matter of fact, the qualities of good iron plates no more resemble glass than leather, and whilst—if the armor manufacturer had to deal with either of the latter substances—he would find it almost impossible to modify their peculiarities, he can easily modify the qualities of iron so as to approach quite close either to the hard and brittle character of the glass or the soft and ductile nature of the leather. Such an illustration, therefore, proves nothing, as far as armor is concerned.

Whatever be the nature of the effects produced, they are caused by what has been designated as useful energy. Punching is produced by concentrating the striking energy on the smallest possible space of the armor, and racking is produced by spreading it effectively over the largest space. Whatever work is expended in producing one effect is, as a matter of course, so much lost from the production of the other. Therefore, in dealing with the subject the mind must never lose sight of the fact that the whole question is resolved into the one of the *most effective* distribution of energy.

The spherical and the pointed projectiles represent the instruments for producing the extremes of the two results. Instead of wandering about in the mazes of possible effects, it is proposed to show the obstacles encountered with the two systems. First, then, with regard to punching. In this case the striking energy is concentrated on the smallest space possible. If there is energy enough to overcome the armor and to spare, the projectile will go through, and then, by its surplus energy, be carried much further on, but its small size and its direction *may* keep it from damaging any of the objects protected. It is the chief object of projectiles to harm the objects protected, and, if this projectile has not harmed them, all its surplus energy is turned to waste instead of being changed into useful energy by rack-

ing, and thus preparing the way for following shots. On the other hand, of all descriptions of projectiles striking armor with a given energy, that one will be more certain to reach the objects protected which concentrates its energy on the smallest space of the armor. The shape of the elongated one gives the particles of metal of which it is composed the best possible support in overcoming resistance, thus permitting the use of shells, and the artillerist takes advantage of this quality in utilizing the shell-charge to increase the *distribution* of the surplus energy, as well as to give new energy to the broken pieces, thus really attaining the object sought.

Second, with regard to racking. The projectile itself does not pierce the armor, therefore its main object, which is to harm the objects protected, is not attained. Its form is the worst possible for mutual support amongst the particles, therefore shells cannot be used with effect. On the other hand, the energy which caused the elongated projectile to simply bore a hole and then fly on into space, has been utilized in straining and disintegrating plate, backing, and fastenings, and all the work of this kind accomplished by one shot is so much relief for the next shot striking in the vicinity, aiding it to get through and do harm.

It has been shown what a very important factor that of the waste energy is, produced by the resistance of the air. Now, of two shots reaching armor with the same energy, the elongated one will have lost much less than the spherical one. The latter, then, must have started with a greater muzzle energy, necessitating either a much higher powder pressure in the gun or a great increase in the weight of projectile, and, consequently, in calibre and weight of gun. The racking system, therefore, leads to a faulty development of artillery, since it requires rapid increase in weight of dead metal and involves a maximum of waste energy. Again, in the racking system the first shot simply prepares the way for the following one, which must strike in the vicinity; but, as the shot is so made as purposely not to penetrate iron, just in that degree will the air offer more effective resistance, and thus destroy accuracy of fire, which is the prime condition of success and which should be developed to the highest degree in naval guns, owing to the unsteadiness of the gun platform. Thus it is seen that, to obtain the best racking effects, accuracy must be sacrificed, whilst to benefit from racking it must be preserved. The spherical projectile, to get beyond the armor, must be solid, while the demands for the greatest possible distribution of surplus energy can only be fulfilled by shell.

It has already been stated that both racking and punching effects are produced by all projectiles, also that the qualities of metal plates permit the armor manufacturer to develop their resisting qualities in either direction; when, therefore, a certain projectile strikes a certain plate and smashes it like glass, it is not an evidence of the excellent system of the artillery, but of the poor quality of the armor. It is in this particular that the advocates of the extreme racking theory have fallen into error. Starting with their illustration of the bullet and the pane of glass, they closed their eyes to the fact that glass was an unsuitable armor, as proved by the experiment, and, other materials being available possessing entirely different qualities, a slight change on the part of the armor would destroy at once all the superiority of the pebble-throwing, whilst the bullet would still be effective. Those who advocated the racking theory cited as one of the strongest arguments, or rather evidences, in their favor, the effects of the 10 inch spherical shot on the side-armor of the monitors during the different attacks on the Charleston forts. Instances were frequent where whole sections of the side-armor were started off clear of the backing, sometimes as much as four inches, so that apparently another blow in the vicinity would have knocked it off; in one case a portion of the Weehawken's backing was actually laid bare. This did not happen, however, on account of the absolute racking power of the 10 inch projectile, but it was entirely due to the weak system of fastening the armor on. Had this evil been cured, it is absolutely certain that the plates would not have started off. The evidence of this fact existed in the conduct of the armor of the Ironsides, which was never started off in the slightest degree, owing to the manner of securing it to the backing, as will be shown further on.

Another argument against the racking theory is well put by Captain Noble, of the Royal Artillery, in a paper written by him in 1865, which was as follows:

"The champions of the 'heavy-weights' say that the heavy shot at low velocities will shake the plate off and break all the bolts, and no doubt such results would be most effective—*if they took place.* However, up to the present date these results have not taken place; the plates in the most obstinate manner refuse to be shaken off."

That this assertion of Noble's is absolutely true is susceptible of easy proof in reviewing the results of naval conflict. The forts at Charleston were armed principally with 10 inch columbiads, racking guns par excellence. In all the engagements of the monitors there is

but one instance of the backing being laid bare, and that was due to a local smashing of the plates where three 10 inch shot struck almost in the same place. The record of the blows on the armor is as follows: Montauk, hit 214 times; New Ironsides, 193 times; Weehawken, 187 times; Patapsco, 144 times; Passaic, 134 times; Catskill, 106 times; Nahant, 105 times; Nantucket, 104 times; Lehigh, 36 times. The Keokuk was sunk under Fort Wagner by punching. The Atlanta surrendered from the effects of punching. The Tennessee, at Mobile, did not shed a single plate, nor was her frame shaken from the concussions of over twenty 15 inch shot and whole broadsides of lighter missiles. The Huascar surrendered when cut up by the 9 inch projectiles of the enemy, but not a single plate was racked off, nor were her frames broken by racking. The New Ironsides on one occasion sustained a fight alone against the combined forts of Charleston harbor. She remained in action three hours, holding down the artillery fire of the batteries, until she was obliged to haul out for lack of ammunition to keep up the contest. During this time she was struck on her side-armor sixty times, but an investigation showed her to be entirely uninjured. Not a plate was smashed, or bolt started, or man wounded. These being the circumstances, the question rises: How, under the racking theory, would a sea-fight have been settled with the same forces in action? Evidently both ships would have been forced to steam to their respective home-ports for more ammunition, or have adopted some other method of fighting.

In spite of such positive evidence of the weakness of the standpoint that the armor of a ship should first be racked off and then the destruction of the ship proceeded with, the theory has never lacked firm supporters, and every armor experiment in which a plate is badly smashed serves as a text for those who either will not or cannot distinguish between a certain plate unsuited to the force brought against it and the general theory of development of guns as opposed to armor. Racking effects always have been and always will be apparent in a greater or less degree, and they cannot be neglected in the study of armor experiments either by the artillerist or the armor manufacturer; but in laying down the principles of the true development of *artillery*, it must never be forgotten that, as will be abundantly proved hereafter, the armor manufacturer has the power through the qualities of his metal, be it iron, steel, or a combination of both, to so modify racking effects as to almost nullify them.

Turning now from the artillery to the armor side of the question, it is well to see in which direction the development of armor will be the most hampered. The main object to be accomplished in the development of armor is to protect the vulnerable things behind it. The secondary object is to furnish this protection with as little loss to itself as possible. In the discussion of the punching and racking theories, it is odd to notice how frequently the relative importance of these objects is changed. As an example, the case of the Spezia target trials in 1876 is cited. (This experiment is fully detailed in chapters IV and V.) A shot from the 100 ton gun struck an iron plate and pierced the whole target, making a hole about four feet in diameter, and creating great havoc by the splinters flying behind the target. The effects of the blow were, however, in a manner localized, as a large piece of the plate remained firmly attached to the backing, whilst the broken parts were all very large pieces. A second shot striking a steel plate of the same thickness knocked almost the whole plate off the backing and smashed it into comparatively small pieces, but the shot did not get through the target, and not a single splinter or piece of projectile fell behind it. It was argued by many from this that the iron plate was the better armor. No doubt it was the better for self-preservation, but the steel plate had accomplished the main object. It had given protection to the objects behind it, even at the cost of complete sacrifice of its own consistence. The iron plate had not done so. The question of what a second shot would have done on both targets could not enter. The iron plate had let the first shot through, therefore it was fair to assume that it would let a second one in. The steel armor would let the second one in, but it had kept the first one out. As those plates actually existed, the superiority of the steel one as a defense against the 100 ton gun was indisputable; it is only in treating the question of the true *direction of development* that the action of the steel could be criticized.

Taking the case of an armor-plate made of wrought iron, and of the qualities shown in armor manufactured about 1856, that is, a plate of undeveloped iron armor, it would be found hard and brittle in its nature, whilst its many imperfections of manufacture made it easily penetrable. The quality of hardness tended to alter punching strains into racking ones, whilst the qualities of ductility and tenacity tended to circumscribe racking strains (but not to reconvert racking into punching strains, as is often argued: all racking forces are *components* of the original punching force). As improvements in manu-

facture were made, it was found to be an inherent quality of the metal that hardness could not be retained without the accompaniment of brittleness. Here was a circumstance hampering the development, in that any attempt made to decrease the punching effect only served to increase the racking effect without increasing the quality of the armor to resist racking. On the other hand it was found that the ductility of the metal could be increased without reducing its tenacity, that is, the racking effects could be more circumscribed without decreasing the resistance to punching. This, then, was the line of development followed with wrought-iron armor, and it was the true one with respect to the metal wrought iron. Notice here, however, that it has already been shown that the true development of the attack was in the direction of punching, and that this development of the defense, whilst circumscribing racking resistance, did not increase punching resistance; therefore, as the energy of projectiles increased, the armor had to be made thicker in order to resist punching; weight increased in direct proportion to thickness, and as in ships' armor the limit of weight that can be allowed for armor is soon reached, *the limit of development of wrought-iron armor for naval use* was soon reached.

When this limit was reached resort was had by the armor manufacturer to a new material, which actually was harder than wrought iron without being notably more brittle. At the same time its tenacity and ductility were such as to circumscribe racking effects to narrow limits, and it is this new material which, under different forms, is now being developed. By this demonstration it is sought to bring out a point of especial importance, which should never be lost sight of by the student, and which is, the distinction that should be made between *true* and *actual* development. The latter may be a wise one for the accomplishment of a temporary object, but unless it starts from a true basis it cannot be lasting in its effects. The development of armor, as it has actually occurred, is a striking instance of this difference. Since the true line of development of artillery was in the direction of the punching theory, that of armor should have been in the direction of resistance to punching, or in increasing hardness without the sacrifice of other qualities. Wrought iron was the first metal used, and its manufacture offered greater scope for rapid improvement than did that of steel. Whilst, however, an immediate necessity existed for armor, there were practical difficulties connected with steel manufacture which prevented its immediate development,

and at the same time the inherent qualities of wrought iron prohibited the true line of development as long as it was used. Foreign experts, as a rule, have always accepted the development of wrought-iron armor as a necessary evil, clearly foreseeing its limits.

At present, discussion is rife amongst those interested in armor development as to the correctness of the *change in opinion*, due to the introduction of steel and compound armor, from a support of the punching to that of the racking theory. In this, however, there is much confusion. The true theory in the development of *artillery* is now, as it always has been, that of punching. Conversely, the true theory for *armor* development is now, as it has been, that of racking; that is, of offering increased resistance to punching. Wrought iron was developed on the other theory as a matter of absolute necessity and to meet existing exigencies, but, as will be seen hereafter, when the development of steel had progressed to a certain point, a complete and most sudden revolution took place, but this revolution was no surprise to those who had carefully studied the subject; it was in fact forced by them, and the only resistance to the change is in the ideas of those who, in discussing the punching and racking theories, lose sight of the fact that since artillery and armor are directly opposed to each other, the theory which is true for the one must be false for the other.

However difficult it has been for artillerists to economize waste energy and to utilize to its fullest extent the striking energy of projectiles by overcoming the obstacles before-mentioned, there still remains to be considered another and by far the most important source of wasted energy; one that confines the artillerist to narrow limits in his attempts to counteract its influence, whilst the armor manufacturer has the aid of both the constructor and the commander of a ship in developing it. This source is the angular position of armor with regard to the line of fire; which diverts the striking energy from direct action, utilizing barely sufficient to throw the projectile off and thus turn all of the remainder to waste. In an oblique impact, the greater the initial surface of contact the easier will the armor throw off the projectile. A cutting edge becomes an absolute necessity for the shot to enable it to bite the armor and hold on whilst it transfers its energy. In all naval conflicts the great majority of hits will be oblique, for in addition to the permanent obliquity given to the armor in construction, there is the constant alteration in position between the vessels engaged. If no other reason existed for condemn-

ing spherical projectiles, this alone would be sufficient, that its shape forbids the application of a cutting edge.

Even with the pointed form this faculty of *biting* is quite limited. The point-angle of a long ogival is about 40°, and with hard-faced armor it will not bite much beyond this angle. If a flat face be used, which gives a cutting edge, accuracy of flight must be sacrificed, and much of what is saved on the chances of oblique impact is lost in increased resistance to the air in flight.

On the other hand, the armor manufacturer and the naval constructor are only limited in this development by the question of weight. When a given vertical surface requires protection, the armor must be made thinner as it is inclined, in order that for the same vertical height complete protection can be given for the same weight. This applies equally to both side and deck-armor, since the latter is a protection from a more or less plunging fire, and is a question, therefore, of vertical protection.

The main points to be considered in reviewing the development of armor having thus been discussed, may be briefly summarized before passing to the descriptive part of the growth of plates, backing and fastenings, as follows:

1st. The greatest exertions of artillerists have so far only succeeded in increasing the absolute amount of muzzle energy about 30 times beyond what it was when armor was first introduced. In this connection it may be well to state that the utilized force of the gunpowder has been increased from about 50 to 90 per cent.; that is to say, that whilst in the old guns about half the total work which a charge was capable of doing was wasted, only about 10 per cent. is lost now, through more perfect combustion, no windage, sealed vents, &c.

2d. The resistance of the air is so great a cause of loss of energy that, aside from any purely punching capabilities of a projectile, its ability to pass through air readily is a matter of the greatest importance in determining the shape of an armor-piercing projectile.

3d. The deformation or breaking up of a projectile on armor is a feature requiring close examination in estimating the resisting power of any specified armor. This point will appear much plainer in the discussion of actual experiments.

4th. In studying the development of armor the causes of the results must be carefully examined. If a plate is punched, not only must the power producing the punching be known, but the combination of the armor must be examined to find out whether the gun is strong or the

armor weak, and, if the latter be the case, to see if the remedies for the weakness can be applied. The same is the case if a plate is racked.

5th. Having reached an understanding of the resistance of armor to normal impact, which is the best condition for the gun and the poorest for the armor, the possibilities and results of the oblique dispositions must be studied, together with the modifications in effect which they cause.

6th. In studying the development of armor it must not be taken for granted that every step taken was an advance in the true direction, therefore a thorough examination must be made into the limiting circumstances. It is not sufficient that because a nation, no matter how powerful, has adopted a certain type or disposition of armor, that the same should be applied elsewhere; and to no class of people is this caution more necessary than to United States naval officers. In the United States there are no armor manufactories, and sooner or later the industry of armor-making must be cultivated. When this cultivation commences it must, in order to be of use, follow the absolutely true line of development, and it will not do to commence with wrought iron, simply because excellent results have been obtained with it, or with compound armor, because Great Britain uses it, or steel armor, because it has won victories over compound, or chilled iron armor, because it has performed wonders. Principles must be studied and experiments must be analysed, not for what they do at the moment, but for what they may be made to do, and a clear distinction must always be made between true development and the satisfaction of an exigency.

II.

Iron Armor and Smoothbore Guns in Europe.

To the French Government must be accorded the credit of first systematically investigating the action of projectiles on solid substances. It is true that before their work commenced, Sir Isaac Newton, Robbins, Hutton, and Rumford had made experiments in this direction, but their researches had been in pursuit of general laws of atmospheric resistance and of the forces of fired gunpowder. About 1830 experiments were carried on at Metz to establish the laws of resistance, or rather to find the coefficients of penetration of projectiles into earth, wood, and different types of masonry. These experiments were continued at intervals for several years, and results were obtained at that time which hold good at present.

In 1841 General Paixhan, who a few years before had revolutionized naval artillery by the invention of the shell, recommended the application of iron plates as armor to the sides of vessels for protection against the havoc of his own missiles, and, although his plans were rejected by the French Government, attention was drawn to the subject of naval armor, and a year afterward the action of the United States Congress, with regard to an official report made to it treating of the resistance offered by iron plates to projectiles, led to the first serious armor experiments.

The American report referred to was one made by Robert Stevens, of Hoboken, New Jersey, to a Committee of Congress on Coast Defences; in which, after submitting the designs of a steam, armored war-vessel, he published certain laws of penetration of projectiles into iron armor, established by him from a long series of experiments. These laws were at once made the subject of investigation both in France and England, whilst in the United States this report led to the laying of the keel of the Stevens Battery, by order of the Government, in the spring of 1854, a few months earlier than the commencement of the first ironclad in Europe.

Practical results in ironclad building were first attained in France. Two months after the keel of the Stevens Battery had been laid at Hoboken, those of the batteries Devastation, Lave, Tonnante, and Congreve were placed on the blocks at Toulon, and a few months

later the English Government commenced the construction of the Erebus, Terrible, and Thunderer. On the 17th of October, 1855, the French batteries (except the Congreve), forming the first ironclad squadron ever seen, received their baptism of fire under the Kinburn Forts, which, after having held the combined fleets of France and England at bay, were silenced in four hours by the ironclads. These floating batteries were of about 1600 tons displacement, and their speed was almost a scant four knots—barely sufficient to enable them to manœuvre in still water unaided. The armor consisted of $4\frac{1}{2}$ inch solid plates, backed by $27\frac{3}{4}$ inches of oak, and their batteries were composed of 16 guns, of the type known as the French 50, corresponding closely to the English and American 68 pdr. shot-gun. They took up positions on the day of the action at ranges of from 870 to 1100 yards from the main fort, which was armed with guns corresponding to the 32 pdr.

The Devastation was hit 64 times and the Tonnante 65 times, but the armor was uninjured, the shot marks being only about $1\frac{1}{4}$ inches deep at the maximum. Three shots went through the ports of the Devastation, killing or wounding eight men, and two through the ports of the Tonnante disabled nine men. Each vessel during the action expended about a thousand projectiles.

The English batteries were slightly larger than the French, having a displacement of 1850 tons. The armor plates were 4 inches thick with a backing of 24 inches of oak, composed of the solid frame, inside and outside planking and an extra outside course of plank, and the batteries were composed of twelve 10 inch shell-guns, whose individual power, as will be seen from the table in the foregoing chapter, was somewhat inferior to the 68 pdr., owing to the hollow shot and light charge used. The plates of both the French and the English vessels were fastened to the backing by through-bolts, about $1\frac{1}{2}$ inches in diameter, spaced about one foot apart around the edge of the plate, having countersunk heads flush with the face of the armor, the inner end of the bolt being threaded to set up with a plain nut. Attention is called to these points of backing, fastening, battery power and loss in action, as they are all necessary to an understanding of the causes of future modifications.

This comparatively insignificant action at Kinburn, which had but little if any effect upon the course of the Crimean war, changed the whole condition of armor for naval use from one of speculation to one of actual and constant necessity.

It is not the intention to follow the development of the ironclad, except in so far as is necessary to explain the various modifications in the construction and arrangement of armor; but before leaving the subject of the ship itself, it is necessary to correct a very general impression amongst Americans that the introduction of the ironclad was principally due to the steps taken by the United States in creating a fleet at the outbreak of the civil war. This is by no means the case. The orders for the construction of the Monitor, Galena and New Ironsides, the first ironclads built for the United States, were issued in September, 1861. Prior to this time, as has been shown, England and France had each constructed a squadron of floating batteries; these squadrons were quadrupled in size and rendered doubly powerful in individual ships within the next four years. In 1858 the first squadron of sea-going armored frigates, Gloire, Normandie, Invincible and Couronne, was commenced in France, and scarcely were their keels laid when England responded to the advance with the Warrior, Black Prince, Defence and Resistance. Before the United States Congress had considered the question of ironclads, England, France, Spain, Italy, Austria, Denmark, and the Southern Confederacy, either had ironclads afloat or on the stocks. Before Ericsson had submitted the design of the Monitor to the Naval Commission, Captain Cowper Coles had demonstrated the advantages of the turret, mounted on low-freeboard ironclad hulls, in public, to the naval experts of England (see Proceedings of the British United Service Institution, June 29, 1860). Before the United States had closed the contract with Ericsson for the Monitor, the Danes had made one with Coles for the double-turreted sea-going ironclad Rolf Krake, the progenitor of the Huascar and more closely resembling her than the Nantucket resembled the Monitor. The keel of the Rolf Krake was on the stocks before that of the Monitor was authorized. Before Americans had boasted of the herculean task of building the Monitor complete in ninety days the French had applauded the feat of finishing an ironclad in thirty-seven days from the date of laying the keel. (This was in 1859, at the outbreak of the war with Italy.) While the Monitor was hanging between life and death at the end of a tow-line on her first sea-passage, a French ironclad had breasted the waves of mid-ocean alone, with her head to the westward; and while Americans in the North spoke with awe of the invulnerability of the Monitor, the guns of the Normandie rang out a challenge in Vera Cruz to the United States to dare to interfere in the establishment of the Mexican Empire.

For the few years immediately following the introduction of armor the 32 pdr. and 68 pdr. shot-guns were the only recognized armor artillery, for although the 8, 9, and 10 inch shell-guns had been developed before the first ironclads were built, they were inferior in power to the 68 pdr. and were never used against armor, except in a few cases, and even then no noteworthy results were obtained. The first appearance of the 11 inch smoothbore as an armor-gun was in the action between the Monitor and Merrimac, and the 15 inch was introduced in 1862 on the monitors of the Nantucket class. Rifled guns stopped the development of the smoothbore in Europe at the 68 pdr., and sheer cumbersomeness stopped it in the United States with the 15 inch.

With regard to the condition of armor manufacture during this period, it may be safely asserted that since the first armored vessels were built in 1854, prior to that date the manufacture of plates for armor had not become a distinct industry. In fact, although the manufacture of boiler plates was quite well developed at this time, even they could only be considered as possessing fairly good resisting qualities. Between 1854 and 1858 armor manufacture was limited in thickness of plates to 4½ inches, and but little dependence could be placed in regularity of quality even with this low thickness. The welding was imperfect, the best composition of ores to produce desired results was not known, steely spots, burned metal, layers of scoria and scale, blow-holes and other imperfections were common and had to be accepted. At first the only rolls available for making armor were such as were used for boiler plates, and these were too light for the requirements. In consequence, the metal was shaped almost entirely under the hammer, which naturally would give results much more irregular than rolling. Time was required to design and put up the proper rolls, so that the real improvement in the condition of armor plates cannot be said to have commenced much before 1859, and it is about this time that the first real increase in thickness of plates from 4½ to 4¾ inches becomes noticeable.

As has been stated, it is a matter of official record that members of the Stevens family had established certain laws with regard to the resistance of armor, amongst which was one, that a thickness of iron of 4 inches, inclined at an angle of 45°, was invulnerable to the artillery of 1842. The experiments from which these results were obtained are unfortunately not available, but it is more than probable that the great majority of them were with laminated plating,

as other material than boiler plates could only be obtained with the greatest difficulty. At the time that this official report was made the English had just commenced the thorough introduction of steam into the navy, and the importance of this element demanded a greater amount of protection than could be furnished by wooden hulls. The Admiralty, therefore, in 1843 decided to duplicate the Stevens experiments, and to this end a target was constructed at Woolwich consisting of 14 plates of boiler iron riveted together, of a total thickness of 6 inches, bolted to a backing of 24 inches of oak. Against this target 68 pdr. and 32 pdr. shot were fired at a range of 400 yards. 22 shots in all struck the plates, eight of them breaking the iron completely, but none getting through. The rear of the target was badly broken.

Experiments against laminated plating were at this time carried on at Gavres, which were very interesting in their results. In the first series it was determined that the 32 pdr. solid shot, with an energy of 485 foot-tons, would not pierce twelve ½ inch plates riveted together, whilst with an energy of 340 foot-tons it would pierce a target of nine ½ inch plates. The second series was made to ascertain the protective efficiency of coal-bunkers. The target consisted of a section of a frigate's side through a bunker abreast the engine, with a thickness of oak of 24 inches, a width of bunker of 4 feet, having a ½ inch plate for its inner side, and midway of the bunker a hanger of four ½ inch plates riveted together. The bunker was filled with coal both sides of the hanger. This target was found to resist all projectiles, both solid and hollow, and the Commission reported that, as in their opinion the firing conditions (the gun only 12 yards from the target) would never be realized in practice, the depth of the bunker might be reduced. This report is of more than ordinary interest, since it offers decisive proof that as early as 1844 coal-bunkers were utilized as a protection for machinery.

In 1845 Dupuy de Lome submitted his first project for an armored frigate. By substituting iron for wood in the hull he hoped to reduce the weight from 42 per cent. of the displacement to 23 per cent., and this saving he proposed to utilize in an armored belt 8 feet wide at the water-line, of a thickness of 6½ inches.

This first proposition was rejected by the French Navy Department, for the reasons that he had overestimated the saving in weight from the substitution of iron for wood, and even with that allowance the 6½ inch laminated belt was not considered invulnerable, and the battery was left without any protection. In 1846 French constructors

were invited to submit designs of an armored floating battery for coast defence, and one of the designs, contemplating a hull of iron, was at first accepted, as the lightness of hull permitted an increase in thickness of armor, but shortly afterwards it was condemned, on account of fear of deterioration and great loss of speed from fouling.

No further steps in this direction were taken till the outbreak of the Crimean war, when the development of designs for floating batteries was ordered to be made at once and experiments were carried on at Vincennes to determine the proper armor. At this time the necessity for backing to aid the resisting power by its elasticity had been fully recognized, and it had great weight with the French in causing them to retain wooden hulls, since the wood served the double purpose of framing and backing, whilst with an iron hull the additional wood backing more than absorbed the saving in weight caused by the substitution. In these Vincennes experiments comparative tests were made between solid and laminated plating, showing a great superiority for the former. 4-inch solid plates were broken but not pierced by the 32 pdr. solid shot at twenty yards. The same effects were produced by the 8 and 9-inch hollow shot. From these results it was decided to armor the batteries with 4½-inch solid plates.

The English Admiralty having accepted the invitation of the French Government to construct batteries corresponding to their own, carried on a series of experiments in September, 1854, at Portsmouth, to determine the proper armor. Seven 4½-inch plates were bolted to a solid oak backing, and were tested with the 32 pdr. and 68 pdr. Ten rounds from the smaller gun at a range of 360 yards hit the target, the maximum indentations being two inches. Four rounds striking one plate cracked and bulged it quite badly, but the backing was not materially injured. Two rounds from the 68 pdr., at 1250 yards, each cracked a plate completely across with a maximum indentation of 1½ inches; backing not injured. Ten rounds from the same gun, with a slightly reduced charge and at 400 yards range, cracked the plates badly and knocked some pieces of plates off. Seven more rounds, with the full charge at the same range, finished the destruction of the target, only one plate being left standing. This test was considered as being quite satisfactory, and 4½-inch plates were adopted for the armor.

The fabrication of the plates for the armor of these first batteries was a matter of the greatest difficulty. The worst trouble appears to have arisen from the prevalence of steely spots in the plates, which broke up the tools used in finishing and boring. The inspection was

necessarily given wide limits. There was no experience to form a guide in this respect, so that the manufacture was only carefully watched to gain the necessary knowledge, and the plates were only limited in tests for reception to the indications of specimens. In France test plates were made of several different mixtures of iron, and were tested for strength in the tensile machine and under the hammer. In this way a standard was established, and the armor was all made of the same mixture. In the process of welding up the packets the fag-ends were cut off and worked separately. They were then given the pulling and hammer tests to show the fracture, and if they failed to come up to the standard specimen the whole batch of plates was condemned. This was a very crude method of testing armor for reception, but was unavoidable at the start.

One of the first steps taken in England after the construction of the batteries was to have ordered a number of plates from all the prominent iron manufacturers. No limit was placed upon them in regard to mixtures or attained qualities, but having been informed that competitive firing tests would be made, each one was permitted to submit the plate of his choice. Experiments were carried on with these plates in 1856 and 1857. Some of the plates submitted were of steel, although these were but two inches in thickness. It was during these tests that the great difference between the effects of wrought and cast-iron projectiles was noticed. In the summary of the official report on these tests the following notes are made: "Plates of four inches offer a good resistance to cast-iron 32 pdr. and 68 pdr. shot at 600 yards, but at 400 yards they offer little and are broken up. A repetition of the blows, however, at both ranges destroys the plate. The steel plate is much inferior, offering no effectual resistance, the shot going clean through it and the bulkhead."

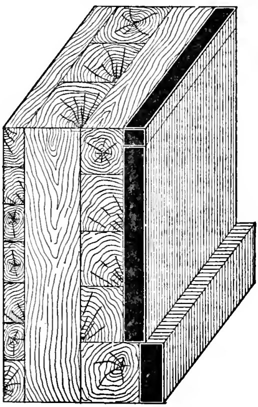
These notes show a very strong racking effect for the projectiles, as was to be expected in the early days of manufacture. Only one year afterward, however, the following summary appears with regard to the effects of 68 pdr. shot on another 4-inch plate:

1st. At 400 yards the wrought-iron plates 4 inches thick resist every description of projectile, even 68 pdr. wrought-iron shot, for a considerable time; hollow shot, red-hot shot and shell make little impression on them.

2d. At 200 yards the effects of the projectiles have much increased, and the plates are sometimes penetrated with the heaviest wrought-iron shot and the frame of the ship much shaken. Hollow shot, red-hot shot and shell do little damage at 200 yards.

3d. At 100 yards the effect of the projectile is much greater. The 68 pdr. cast-iron shot generally penetrated deep into the wood after passing through the iron plate; still, none have passed completely through, excepting those striking in holes previously made. The 32 pdr. shot at 100 yards penetrated deep into the plate, but not into the wood, and did very little damage to the frame of the ship.

4th. At twenty yards the cast shot did very little more damage than at 100 yards. If, however, the shot does penetrate the side it carries with it showers of splinters and fragments of iron, doing far more damage than had the projectile only passed through the wooden side.

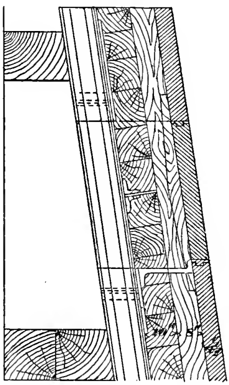


Gloire.

It was about the time that this report was made that the designs of the Gloire were finished and the ship was laid down. Armor manufacture had developed in France far enough to permit regular firing tests to replace the crude method of statical testing before mentioned. The remarkable advance in plate making is strikingly shown in the experiments for establishing a standard test-plate for the Gloire's armor. In February, 1859, four French firms (amongst which were the celebrated Schneider & Co., of Creusot, who had furnished the armor for the original French batteries, and Petin et Gaudet, who for a time were the best armor-plate manufacturers in the world), submitted competitive $4\frac{3}{4}$-inch plates. Each plate was tested by firing three 68-pounder shots with seventeen pounds of powder at a range

of twenty-five yards. The Petin et Gaudet plate won the first place in the test. There was not the slightest indication of a crack on the plate, and the indents were only 3½ inches in maximum depth. This plate was accepted *as the standard for the entire armor of the three first frigates.* It is seen from this that not only was this excellent result considered as capable of regular reproduction, since every plate delivered had to come up to the standard, but the power of the 68 pdr. smoothbore considered as either a racking or a piercing gun had been surpassed by the plate manufacturer. The result was a very natural one; the 68 pdr. smoothbore disappeared from the cadre of French naval artillery, and the Gloire, designed but a year before for a battery of guns of this type, carried a full battery of rifled guns in her first commission.

Unfortunately, no report of experiments on the Gloire's armor as a whole is available. She carried a strake of 4¾-inch plates, backed by twenty-six inches of oak at the water-line, and 4½-inch plates backed by twenty-four inches in wake of the battery. Her backing, as will be seen by the drawing, fulfilled the double object of forming the skin, frame and planking of the ship and backing proper. In order to get an idea of its actual power of resistance it will be necessary to turn to the consideration of her rival, the Warrior.



Warrior.

It would be difficult, if not impossible, to find two sea-going armored vessels of what may be termed a corresponding type, built

within such close intervals of time as were the Gloire and the Warrior, which would show so many and such radical differences in all details, as exist between these two ships. The one was iron hulled, the other wooden; the one had the long clipper bow, the round stern and the full sail power given at that time to the handsomest.frigates; the other was straight-stemmed and sterned, short and of low sail power. The one carried armor barely sufficient to shield the guns, engines and boilers; the other had a perfect-armored side. The Warrior's section through the armor consisted of iron frames ten inches deep, spaced two feet apart, covered by a skin plating $\frac{9}{16}$ of an inch thick, against which were placed two thicknesses of teak backing, the inner one horizontal and ten inches thick, and the outer one vertical and eight inches thick, the whole being faced with armor plates $4\frac{1}{2}$ inches thick. Attention is called to one very important point in the fitting of the Warrior's plates as compared with those of the Gloire. In the latter the plates were plain butted, whilst the horizontal edges of the Warrior's plates were tongued and grooved into each other, with the idea of gaining a greater general strength of structure, especially at the joints. The plates around the port-holes were rolled ones, showing that at this time the superiority of rolled over hammered plates was recognized, the expense of the former being as yet too great to allow of general application. As a farther measure of strengthening, a line of external iron stringers was carried along upon the iron frames between the ports. There was a double thickness of skin plating above and below the line of the ports also. The sum-total of thickness of iron on the Warrior was at the maximum about $\frac{3}{4}$ of an inch greater than on the Gloire, though the latter had the superior resisting power of plate proper due to its $\frac{1}{4}$ inch greater thickness. The backing was much heavier on the Gloire than on the Warrior, but the increased weight was compensated for in that it included the weight of hull also, while in the Warrior the backing was sheer extra weight.

One of the most interesting features of the Warrior's armor disposition, or, as it is technically known, the target, is that it was adopted in England as the armor unit, to which for many years all armor was referred in establishing points of development. In the first experiments against this target rifled guns were used much more than smoothbores, as the days of the 68 pdr. were numbered in that country also by the time that the ship was ready for her battery. The gun, however, did not disappear here as suddenly and completely

as it did in France, and for many years it was used exclusively in testing plates for acceptance up to as late as 1870. The resistance of *targets*, however, from the date of the Warrior's was always determined with the rifle.

An extract from the report of the first series of experiments carried on against the Warrior target gives a very clear idea of the effect of the 68 pdr. against it, although it must be remembered that at the same time a great number of rifled shot were fired.

Warrior target, 68 *pdr. gun, shot* 66 *lbs., shell* 49 *lbs., range* 200 *yds.*

Shell filled with sand.	Hit on upper plate seven inches from the edge. Indent $1\frac{1}{2}$ inches, opened the plates $\frac{1}{4}$ inch and started two bolts slightly.
Shell filled with powder.	Hit on upper plate; tore up four feet of tongue and groove and cracked the plate in two places, cracks seven inches long; drew a bolt $\frac{3}{4}$ inch. Indent 1.8 inch.
Solid shot.	Indent 2.7 inches; one crack seven inches long near the indent; two bolts broken near the port-hole.

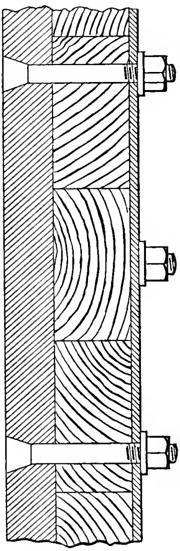
It will be noticed that one shot tore up a long strip of the tongue and groove; other shots showed a tendency to do this also, and the evident weakness of plate thus developed caused the tonguing and grooving to be abolished, and it has never been renewed anywhere with iron plates. The Warrior's plates evidently were harder and less ductile than the Gloire's, as the cracking was distinct, while the penetration was less. At this time, or shortly afterward, French plates were proved to be about ten cent. better in power of resistance than the best English ones.

In October, 1858, a very important series of experiments took place against the sides of two floating batteries at Portsmouth, England, which threw much light upon the subject of the importance of backing. The Erebus was an iron-hulled vessel and the Meteor a wooden hulled one. The part of the side of both vessels used as targets was the section in line with the mainmast, all the main pipes and connections of the engines being immediately underneath and but two feet below the water-line.

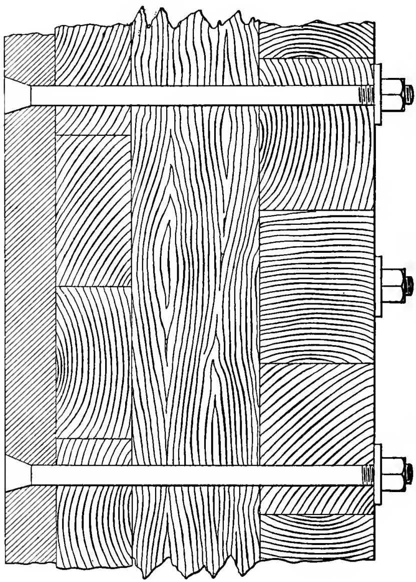
The target of the Erebus consisted of, first, iron ribs, then an inside skin of iron plates $\frac{5}{8}$ inch thick, then outside this five to six inches

oak plank, and the 4-inch wrought-iron plates outside all. Topsides tumble in very much, which causes the shot to glance up a little on striking and so lessens the indentation.

The target of the Meteor consisted of an inner planking of oak, nine inches thick at top, diminishing to four inches at water-ways, then 10-inch oak timbers about four inches apart and filled in solid; 6-inch oak planking outside the timber and 4-inch wrought-iron plates outside all, bolted to the ship's side, with iron bolts passing through all and secured with nuts and screws inside.



Erebus.



Meteor.

Three shots were fired against the Erebus at a range of 400 yards; the first being a 32 pdr., which did no material injury, and the other two 68 pdrs. Against the Meteor were fired nine shots in all: one cast-iron 32 pdr. at 400 yards and one at 300 yards; two cast-iron 68 pdrs. at 400 yards and three at 300

yards; one wrought-iron 68 pdr. at 400 yards and one blind shell 68 pdr. at 300 yards.

The first 68 pdr. against the Erebus broke a piece of plate out 12 inches by 11, and drove it 3½ inches into the backing, although the piece was not crushed; a crack in the plate was made from the top of the hole to the top of the plate. The side was bulged in in wake of the shot, two iron ribs cracked through, three bolt-heads broken off, and the iron skin cracked in two or three places.

The second shot hit near the corner of an upper plate, direct on the head of a bolt, and passed through the side on to the main deck, breaking up as it went through. The shock also broke out a piece of the next plate, over which it lapped slightly, on striking. The plate was cracked across and the butt-end was started out. Several bolt-nuts were broken off and driven across the deck.

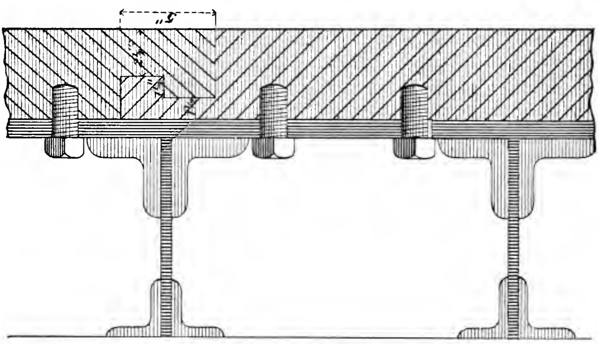
The side of the Meteor was submitted to three times the number of shot that the other was, over half of which were at 100 yards closer range, yet, though the plates were of the same make and size, not one was broken, not a single shot got through, not a bolt-head was broken or nut torn off, and the backing was uninjured. The "general remarks" of the report on the test state that "throughout the experiments with the Meteor it does not appear that the damage inboard would at any time have proved seriously inconvenient to the men fighting the guns; whereas with the Erebus, not only did one shot penetrate her side, scattering the fragments over the gun-deck, but every hit, though not penetrating, caused bolt-heads and nuts to be scattered about the deck, doing apparently as much injury as a volley of grape-shot."

From this it is seen at once what an important factor of the armor the backing is. The thin backing of the Erebus buckled seriously, and the shot striking near the edge of a plate (which was its weakest part), carried it in so far as to break it locally before the useful energy was expended; the broken part canting in the backing, let the broken pieces of shot slip by and through. The same local breaking from buckling occurred in the middle of the plate, except that here the equal strain all around the fracture carried the broken piece in square, and so kept the shot from piercing. As one part of the plate buckled, the outer edges sprang out and thus snapped the bolt-heads, while the corresponding strain on the nut inside tore the inner end of the bolt off and sent the nut across the deck.

Notwithstanding the results obtained from this experiment, it was

considered in England a matter of the greatest importance to get rid of the backing, if possible. Like the armor itself, it was sheer dead weight to the hull of the iron ship, adding nothing to the strength, and the resisting power of the wood to projectiles was not considered worth the great space occupied by it, which hampered the constructor seriously in his attempts to gain speed without sacrificing interior space and strength. Furthermore, it was thought that the perishable nature of the wood would necessitate the renewal of the backing at intervals, which could only be done at a very great expense.

Experiments had been carried on against fortification armor, from which it appeared that a very rigid backing of stone or cast-iron gave increased resisting-power to the plate and lessened the bad effects on the bolts. Since such backings could not be applied to ships, it was thought by Mr. Fairbairn that an approach to this favorable condition might be made by doing away with backing entirely and bolting the armor plates direct to the skin. A target was constructed by his firm at Manchester on this principle, and was tested in 1861 at Shoeburyness. The plates were five inches thick, with hook-joints on the vertical edges and the tongue and groove like the Warrior's plates at top



Fairbairn Target.

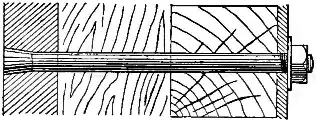
and bottom. These plates were attached directly to a $\frac{3}{4}$ inch sheathing by $1\frac{3}{8}$ inch screws, $7\frac{1}{2}$ inches apart, *tapped 2 inches into the back of the plate.* The sheathing was held by ribs 12 inches deep and 18 inches apart, made of $\frac{1}{2}$ inch plates and angle-irons. This target was experimented with by the 40 pdr., 100 pdr., and 120 pdr. rifles and

the 68 pdr. smoothbore. The plates showed an excellent power of resistance, but the fastenings were soon either sheared or broken off to such an extent as to let plates fall from the target, and the skin was ruptured in several places.

Altogether, however, it was considered worth while to renew the experiment with some modifications in the target, which, when set up, was known as the "Committee Target." It consisted of a 4½ inch rolled plate attached to an iron skin *one inch thick* by through-bolts with nuts and countersunk heads. The same guns were brought to bear against it, and the Committee reported "that however much the armor plates may be supported by direct contact with a rigid backing of iron, and however desirable it may seem to exclude wood or other perishable materials from them, yet the concussion is so injurious to the fastenings of a rigid structure that, in the present state of our knowledge, it would be unwise to recommend the abandonment of wood-backing."

Two other targets were proposed for test about this time, and in spite of the previous failures, the reputation of the proposers—as in the case of the Fairbairn target—was such as to warrant still another trial. Mr. Samuda, the shipbuilder, submitted one which consisted of a rolled plate 5 inches thick attached to a 1 inch skin, with longitudinal ribs 2½ inches thick at the junction of the plates; a thin layer of rubber was placed between the plate and the skin. Although this target was heavier in proportion to its area than the Warrior target, its resisting power proved to be much less. As an example, a 150 lb. spherical solid shot completely pierced this target, whilst the penetration of a similar shot into a Warrior target was only 13 inches into the wood backing. The other target was submitted by Scott Russell, and consisted of four ⅜ inch plates attached to *two 1 inch plates for backing* and an iron skin of two ⅜ inch plates. Again the 150 pdr. spherical shot punched holes clear through. After this it was declared useless to attempt to apply armor to ship's sides without a wood-backing, for even if holes were not punched clear through, the skin was broken and the frames and stringers were cracked through and distorted, whilst the fastenings invariably showed a vicious tendency to shear. A few experiments were carried on to ascertain the effect of *facing* the plates with different materials. Rubber and felt were found to have no practical effect whatever, whilst with wood, or wood backed by an iron skin, one or two live shells were sufficient to tear the facing off in large masses.

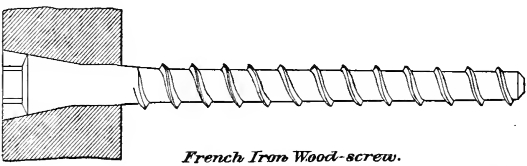
From the earliest period of experiments trouble had been experienced with fastenings. The armor-fastening originally used both in the French and English services had been an ordinary $1\frac{1}{2}$ inch bolt, threaded at the inner end to set up with an ordinary nut, and having



Original Armor Bolt.

a countersunk head. When these bolts were under water the leak from them was a great source of annoyance, as no amount of red lead or putty would keep them tight with the ship working. By far the most serious evil, however, was the liability of the bolt to snap at the bottom screw-thread when the plate was struck and send the nut flying about the deck.

The French were the first to modify the evil, and their first attempt at modification was such a success that their new pattern armor-bolt was retained practically unaltered until comparatively lately. This modification consisted in substituting a bolt of a special form of iron wood-screw, a heavy thread being worked on it with a low pitch to

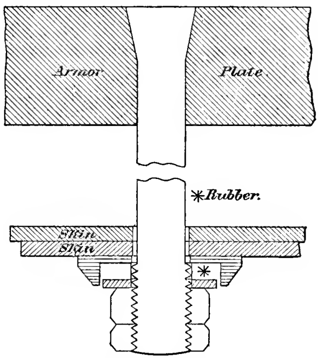


French Iron Wood-screw.

prevent it working loose. The inner end of this bolt was about two inches short of the inner face of the backing, or of the inside of the inner planking. Three objects were thus accomplished at once: There could be no great leakage through the bolt-holes, there were no nuts or bolt-ends to fly about the decks, and—a point of great importance—there was a saving in weight of bolt of nearly one-fourth, which amounted to a matter of tons in the total dead weight. In the first patterns of wood-screws which they made the screw-thread was carried to the inner edge of the armor; but it was found that there

was a great tendency of the bolt-head to shear or snap, so in the Gloire and future ships the full size of the shank was carried back from the neck of the bolt, without threading, about two inches inside of the armor-plate. This made a thoroughly reliable armor-bolt.

In England no decided step appears to have been taken in bolt development previous to 1862, when, at the time of the experiments with the Committee Target, the scheme was tried of inserting rubber washers between the nut and its seat. This was found to give great relief to the bolts and to decidedly modify the tendency to fracture. About this time the name of Sir Edward Palliser appears. In 1862 he was a Captain of Hussars, stationed in Dublin. His attention seems to have been attracted to the tendency of the bolt to snap at



Admiralty Bolt.

the screw-thread, and after a few experiments he prescribed the remedy in a letter to the Admiralty, December 13th, 1862. The cause of the difficulty and the remedy were so simple as, in fact, to have escaped the attention of experimenters, who were looking elsewhere for the trouble. The screw-thread was tapped on the end of the bolt, and thus the last turn presented a smaller cross-section for resistance than the other parts of the bolt. When a strain was brought upon it the stretch of the body of the bolt was less per unit of area than that of the junction at the thread, therefore the metal had to snap there. The remedy was simply either to reduce the diameter of the shank to that of the bottom of the thread, or, what is the same

thing, to work a male thread on the bolt, or else to have a compound bolt, the threaded end being of steel. The first of these remedies was the most simple. Palliser carried on a series of statical experiments which confirmed the truth of his idea, and the modification was adopted.

These two modifications, somewhat improved upon, such as in altering the size of the bolt itself, double nutting and providing a saucer for the rubber washer, are represented in the Admiralty bolt shortly afterward adopted.

Mention has been made of the effects of the 150 pdr. spherical projectile on the Warrior, Samuda and Scott Russell targets, and before considering the heavy American smoothbores, a few of the shots from this gun and the Horsfall smoothbore 300 pdr. will be quoted to show their effects upon the Warrior target, thus connecting the series of European smoothbore experiments with the American ones. The 150 pdr. was not a regular smoothbore gun, but it was the Armstrong 300 pdr. muzzle-loading rifle, which was tried as a smoothbore before being rifled. It was used thus in 1862, firing solid shot of 150 pounds weight with forty and fifty pounds of powder, the initial velocities being 1726 and 1756 feet, giving with the latter a muzzle energy of about 3250 foot-tons.

The first shot on the Warrior target, with forty pounds charge, smashed the plate, broke a part of the tongue and groove, fractured and bulged in the skin, broke a rib and broke off two bolt-nuts.

The second shot on the same plate smashed it completely in, knocking off about two square feet entirely and splintering the backing. The skin was badly broken, as also a second rib. Large irregular hole through, and parts of the broken shot carried through with the splinters.

The third shot, with fifty pounds charge, struck a new plate and made a clean hole through the armor eleven inches in diameter. The fourth shot, with the same charge, had a like effect on another plate.

The Horsfall gun was a 13-inch wrought-iron piece, firing a projectile of 280 pounds with a charge of 74½ pounds, the initial velocity being 1130 feet and the muzzle energy about 2480 foot-tons.

It is unfortunate that the plates of the Warrior target, against which it was tried, were declared to be inferior in quality, being very brittle. The range was 200 yards, and the first shot completely penetrated the target, making a hole about two feet square, smashing

the plate considerably, stripping the tonguing and grooving, starting several bolts, breaking off five bolt-heads, breaking two ribs and cracking a third. About three square feet of the skin were torn off and more of it badly shaken. Other shots fired on the same target produced equal effects, or would have done so had the target not been so much shaken that the effects were exaggerated.

From a careful study of the experiments carried on during this first period, a true idea may be gained of the direction and amount of development of iron armor. At first it was considered impossible to even provide the water-line of a vessel-of-war with an armor-belt. Such was the judgment given by the best French architects of the day to the scheme of Dupuy de Lome, who afterwards not only covered the water-line, but the whole side of the Gloire with armor. The necessity for a protection to the engines and boilers of the new steam vessels was recognized, but experiment showed that 6-inch laminated plating was barely sufficient to contend against the 32 pdr., while it availed nothing against the 68 pdr. This was in 1843. Ten years after, laminated plating was condemned, while the 4½-inch plate was found to withstand the 32 pdr. quite well at twenty yards. In another year that gun was forced out of the line of armor weapons, and it was reported that the 4½-inch plate is proof against the 68 pdr. at 600 yards, except to repeated blows on the same plate. In 1857 both France and England find the 4½-inch plate thoroughly proof against the 68 pdr. at 600 yards, even with wrought-iron shot. In 1859 the French plates *must* be proof against the 68 pdr. at twenty yards in order to be accepted for armor. In 1860 the English report that "vessels clothed in rolled iron plates of 4½ inches thickness are to all practicable purposes invulnerable against any projectile that can at present be brought to bear against them at any range." These reports, all having reference to the same thickness of plate, tested always by the same gun and charge, or, as it may be better stated, by the same striking energy, show the rapid progress made in plate manufacture. More than that, they show clearly the capabilities of iron to adaptation as armor.

Previous to 1850 so high an authority on all matters pertaining to artillery as Sir Howard Douglas gives judgment against iron, as a proper material for armor, on account of its extreme brittleness. Ten years later the perfections of manufacture have nullified this fault. Alarmists were still to be found who declared that increased ductility was only to be attained at such a sacrifice to resisting power that

plates would be as easily penetrable as wood; but Fairbairn, with his careful statical experiments, found that the resisting power against punching was not necessarily decreased by an increase of ductility. Armor bolts, which at first snapped or sheared, were made to hold securely against the heaviest shocks, and the necessity for backing having been determined its thickness had been fixed upon.

Against such developments as this the 68 pdr. could not contend, for before armor existed the gun had reached the limit of its development. The rifle had been introduced and its advantages had at once been appreciated. The day of the smoothbore was over, and before 1860 this type of ordnance had been practically stricken from the list of naval artillery in Europe.

III.

Iron Armor and Smoothbore Guns in the United States.

There appears to be a universal agreement between United States and foreign authorities in according to an American the credit of the first modern *practical* exposition of the value of armor for naval use. John Stevens, of Hoboken, New Jersey, designed a vessel and submitted the plans to the United States government during the war of 1812, one of the special features of which was a battery protected by inclined armor. Apparently his plans received no serious consideration at that time, but members of his family appear to have constantly worked at the original idea, and carried on experiments with projectiles against armor until 1841, when it appears from an official letter written by one of them to a committee of Congress on Coast Defences that they had determined not only the thickness of iron necessary to stop projectiles at point-blank range, but also the comparative resisting powers of iron and oak. The law which they had established was, that a thickness of from one-half to two-thirds the diameter of a ball (set at an angle of 45°) was sufficient to resist or deflect projectiles, and that the resistance of oak was about one-sixteenth that of iron. Finally, that a thickness of four inches of iron laid over the frames and planking of a ship's side was sufficient to stop the projectiles of any existing artillery. Unfortunately, the data from which these laws were deduced is not available, but it is supposed that most of the experiments were carried on against laminated plating, owing to the great difficulty of getting solid plates more than an inch in thickness at that date.

As a direct result of this letter it was decided by Congress to build a vessel on the Stevens designs, but after this decision had been made, and the preliminary armor experiments ordered by Congress to verify the laws had been completed, the matter rested till the spring of 1854, when the sum of half a million dollars was appropriated to build the ship. Work was at once commenced and continued for twenty months, when, after an expenditure of $700,000, a new Congress refused to appropriate the additional half a million necessary to finish her, and the hull remained unfinished until a year or two ago, when, after an ineffectual attempt to sell it, it was broken up. The ironclad and the torpedo, born in the United States during the war of 1812,

both first showed their power in the Crimea in 1855. The government of the United States had been repeatedly urged to adopt both in its system of defence, but it was left for European talent to reap where American genius had sown. The neglect to provide against the time of need brought its own punishment, for the first ironclad and the first torpedo that showed their power in the United States destroyed naval vessels flying the national ensign.

The report made by Stevens, above alluded to, and the action of Congress thereon, attracted European attention at once. In 1843 experiments with armor targets commenced on the firing grounds of Gavres, Vincennes, Portsmouth and Woolwich, and they have continued in an unbroken series to the present time. In the United States experiments were carried on with many different dispositions of armor, both for naval and military use, from the time of the Stevens experiments up to the outbreak of the civil war, but they were as a rule of a desultory character, and it was not until 1862 that the work on the naval firing ground against armor fairly commenced, at which time the examples furnished in actual battles were giving the best possible experience. Before examining the American experiments, an important peculiarity brought about by the special line of development of United States naval artillery must be distinctly understood.

About 1840 the 8-inch shell-gun came into general use in the service under the name of the "Paixhan Gun," from the inventor of shell-fire. It resembled closely in size and weight the 68 pdr. shot-gun, of which it was simply a modification. General Paixhan, in introducing shell-guns, was the first person to advocate "racking," or rather to bring this subject to the attention of the world. He advocated using a smaller charge of powder than was the rule with shot-guns of a corresponding calibre, in order to lodge the shell in the frames of wooden vessels, thus racking them both by impact and by the explosion of the shell itself. Thus the charges for the 32 pdr. shot- and shell-guns were respectively ten and six pounds, and those of the 68 pdr. and 8 inch were sixteen pounds and nine pounds. Dahlgren modified the design of this Paixhan type so as to secure a less weight and better disposition of the strength of the metal, and the symmetrical form of the Dahlgren design gave to the resulting 8 inch a distinctively American character. As soon as this new gun was introduced into the service it not only replaced the Paixhan, but it forced the 68 pdr. out of use, and from that time the development of naval artillery was turned *exclusively* to the

increase in power of shell fire. The 9, 10, 11 and 15 inch shell guns rapidly succeeded each other, but in this succession a curious error was developed. The proportionate reduced charges were retained in all the calibres for the original reasons above stated, and in the new guns the weight was somewhat reduced in the profile of the gun to correspond with the reduced pressures. This reduction, however, did not practically affect the strength of the piece. Solid shot were supplied to and used by these guns and they formed a certain proportion of the ammunition allowance.

The shot, however, produced a greater strain on the gun for a given charge than the shell, and the naval authorities, apparently forgetting that the guns were originally designed for a high pressure, ordered the charge for the shell to be *reduced* when using shot. In this way arose the ridiculous anomaly of the 68 pdr. using a charge of 16 lbs., while its sister gun, the 8 inch, when using shot—whose only service was to overcome heavy obstacles, thus requiring the greatest energy possible—carried a charge of but 8 lbs. This anomaly was perpetuated in all the guns, thus reducing their power to a very low point. The magnitude of this erroneous development is appreciated in the comparison of the charge used in the 15 inch gun during the war with that found afterward to be perfectly safe. During the war the charge used was 35 lbs., whilst it was found shortly afterward that the strength of the gun permitted the use of 100 lbs. As *shell guns*, the Dahlgren guns deserved all the praise ever given them, but whatever their capabilities might have been as such, as armor guns they were entirely neglected in the Civil War.

The first decisive result of this line of development occurred when the Monitor and the Merrimac came together. The former ship was armed with 11 inch smoothbores. The use of shells was out of the question, and the use of shot demanded the ordinary or 15 lb. charge. The 168 lb. projectile, fired with a 15 lb. charge, gave a muzzle energy of little, if any, over 1300 foot-tons, or only about 150 foot-tons more than the 68 pdr. The Merrimac's armor, inclined at an angle of 30° with the horizontal, consisted of narrow bars rolled from railroad iron, and consequently of excellent material, in two thicknesses, giving a total thickness of 3 inches, laid on over about twenty inches of oak. As far as can be ascertained, no material damage was done by the Monitor's fire to the armor of the Merrimac; nor should it have been expected, for twenty years before Robert Stevens had published the law, founded on experience, that the heaviest artillery then existing (the 68 pdr., using a 16 lb. charge, this being the regu-

lation United States charge for the old 68 pdr. at that time) could not pierce a thickness of 4 inches at an angle of 45°, and certainly the additional 150 foot-tons of the 11 inch projectile were no more than equivalent to the additional 15° of inclination of the armor. Had the 30 lb. charge been used during the action—which doubtless would have been the case if the Government practice had not so carefully excluded it—the muzzle energy of the projectile would have been about 2730 foot-tons, or more than double what it was, and, as was afterwards proved by experiment, both in the United States and in Europe, every fair blow planted by the Monitor in the action would have smashed a hole completely through the armor and driven a shower of splinters and broken pieces of shot about the confined battery-deck. Out of the forty-three shots fired by the Monitor, if the scant allowance of ten per cent. be made for fair blows, the Merrimac must have been forced to a surrender through the havoc caused on her battery-deck.

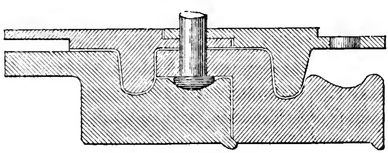
Another point with regard to the artillery power of the Monitor deserves especial attention. A certain number of wrought-iron shot were supplied for the guns, which, as has been shown, were much more powerful than cast-iron ones, in so far as piercing armor is concerned. Owing either to the hurry of manufacture or through carelessness, these shot were not carefully gauged, and the danger of jamming them in the bore in loading caused them to be set aside during the action. It was afterward proved by experiment that even the low energy developed by the small charge was sufficient to cause wrought-iron shot to smash through armor disposed like the Merrimac's. It is not intended in drawing attention to these points to cast slurs upon the practice of the Government during those days of general confusion, arising from the lack of preparation for a sudden war, but rather to point out the very important lessons that may and should be learned by all naval officers, on whom the chances of victory or defeat are imposed by their profession.

As is well known, at the outbreak of the war a special Naval Committee was appointed to examine and determine upon types of iron-clads to be built for immediate service. The report of this Board presents several points of interest in connection with armor work in the United States, as it forms the starting-point of armor development. These points were: 1st. That a thickness of armor-plating of 4½ inches was essential. 2d. That solid plates should be used if it were possible to obtain them in this country. 3d. That these plates should

be rolled ones, in preference to hammered ones. A fourth point deserves transcription *verbatim*. "The question whether wooden backing or any elastic substance behind the iron plating will tend to relieve at all the frames of the ships from the crushing effect of a heavy projectile, is not yet decided. Major Barnard says 'to put an elastic material behind the iron is to insure its destruction.' With all deference to such creditable authority, we may suggest that it is possible a backing of some elastic substance might relieve the frame of the ship somewhat from the terrible shock of a heavy projectile, though the plate should be fractured."

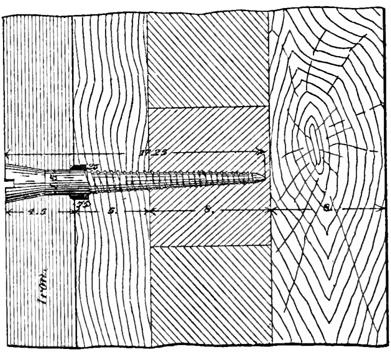
In this opinion the Board seized directly upon the true foundation of armor defence, and under circumstances that made the emission of such an opinion remarkable. The members had examined the records of English experiment and they knew that Major Barnard's opinion was right; for as has been stated, it had been proved in England that a rigid backing like granite or cast iron was superior to wood in the aid that it gave to the resistance of armor plates. They knew that at that very time the English were strenuously working to devise some method by which backing could be done away with. Yet they did not lose sight of the fact that the wall of a fortification and the side of a ship were under conditions which required radically different treatment, and that the question before them was *to save the side of the ship*, and not the armor. The English were led on for a time by the less destructive effects on the armor when iron backing was used instead of wooden, forgetting that a vessel might still hold her own with her armor smashed provided her frames were unbroken, whilst with her frames smashed, her armor was useless, no matter how sound it might be.

The three ironclads ordered by recommendation of this Board, represented three types of ships and armor entirely distinct from each other. The Galena was a total failure, and would not even merit passing notice were it not for the lesson that may be learned from an examination of the method by which her armor was secured.



Galena.

The total thickness of the armor was but 2½ inches, and the absurdly complicated way in which it was put together made it weaker than would have been the case with plain plates. The iron was arranged in bars, so as to show a clear outside surface, free from bolt-heads and with the joints lapped and calked. In so far as exterior appearance was concerned, nothing could have been better. The inner surface, however, was cut and curved in such a way as to give a maximum of racking effect, the idea apparently being to make the plates lap like shingles so that each should cover the fastenings of the next plate before it. In reality the bars were only bolted down one side so that a shot would rack it out of place if it did not break it. This vessel succumbed to the first test under Fort Darling, in an action from which the Monitor came out entirely unharmed.



New Ironsides.

The New Ironsides and the Monitor had not a single point of resemblance either as ships or as armor targets, and as both types were submitted to the most thorough tests possible, much of value may be learned from an examination of them. The former ship was a frigate in rate, carrying a broadside battery, having a wooden hull and solid plate armor. The latter was in size but little beyond the rate of a gunboat, with a concentrated turret battery, and iron hull and laminated plate armor. Although it is somewhat beyond the scope of the subject to enter into the history of a vessel, exception is made in the cases of these vessels, every particular of which should be of the greatest interest to American naval officers.

The scheme of the New Ironsides was due to Mr. B. H. Bartol, of the Philadelphia engine-building firm of Merrick & Co., who submitted the design to the Navy Department. The ship herself, however, was designed and built by the Cramp shipbuilding company of Philadelphia. She was a casemated ironclad frigate with unarmored ends, except that the water-line belt was complete all around. Her armor consisted of 4½-inch solid plates backed by twenty-one inches of oak, the whole inclined throughout the casemate at an angle of 30° from the perpendicular. This armor plating was manufactured at Pittsburgh, and in its disposition bore a very close resemblance to the French system, as applied in the Gloire. The backing was fixed in thickness by the scantlings required for a wooden vessel of that size, some additional increase being allowed for the great extra weight which it was required to bear. The fastenings of the plates were of the French system of iron woodscrews with a single modification designed by the builders. It had been reported that the similar bolts of the Normandie had developed serious leaks on her trip to Vera Cruz, and to counteract this, rubber tubing was countersunk into the outer layer of backing, projecting slightly beyond the countersink, so that when the plate was set back firmly by screwing up the bolt, the rubber would clasp the shank closely and caulk the joint watertight. This method of fastening proved a complete success when submitted to the test of service. Her battery consisted of fourteen 11-inch smoothbores and two 8-inch Parrot rifles, and the ports were closed by means of heavy iron shutters pivoted over head to swing laterally, being on the exterior of the armor. Her speed was but about six knots at best, as the machinery given to her had been built for a corvette of the Wyoming class, but with the help of a good spread of sail she was enabled to hold her place for months together off Charleston.

For two years this ship was submitted to the most severe test that a war vessel can undergo: alternate blockade duty and close action against fortifications. The following extracts from official reports give a fair idea of her qualifications as a fighting ship, in so far as the general subject under consideration is concerned: 1st. From Captain Turner's report of the part taken by the New Ironsides in the general action with the Charleston forts, April 7th, 1863: "Forcing her way up the channel, she received the fire of the enemy generally obliquely, excepting when she fell off one way or the other. One of these shots striking the forward facing of a port-shutter carried it away instantly. . . . The damage done to this ship, with the excep-

tion of the loss of a port-shutter, is not material. . . . The distance at which she received the severest fire of the enemy was about one thousand yards." Extract from the sworn testimony of Commodore Turner before a court of inquiry relative to the fight of April 7th: "She lost one port-shutter, shot away. She had one of her plates cracked by a shot. She had a breeching-bolt driven in. She received a shot on her beak which twisted it a little and cracked it. . . . There was nothing to impair her efficiency in the slightest degree, either in her iron or woodwork. She was as ready to go into the fight ten minutes afterwards as she ever was. . . . No shot or shell entered the ironclad part of the Ironsides. The iron plating of the spar-deck is confined to the wooden deck above it by iron bolts half screw. There were about thirty of these bolts over each gun. Wherever shots struck where there were no sandbags the bolts would be driven down like bullets. One shot did strike where there were no sandbags and the bolts underneath were driven out by the concussion."

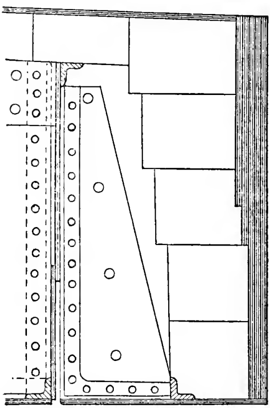
From the report of Carpenter Bishop of the injuries received by the New Ironsides during the attack of August 16th on Forts Wagner and Sumter: "I count in all thirty-one hits, though I think we were struck several times below the water-line. The plating received nineteen shots, eleven others struck the woodwork and eight passed though the smokestack. No material damage was done to the armor, though in four places the iron was so much crushed in as to crack it. The backing, except in one place where one width of the ceiling is driven in about $\frac{3}{4}$ of an inch, shows no signs of having been started. The forward shutter of No. 3 port on the starboard side was shot off. . . . Another shot struck the deck, unprotected by sand-bags, just abaft the partners of the mizzenmast, going through the planking and glancing off as it met the iron underneath. The iron, however, was crushed down to the depth of $1\frac{1}{2}$ inch and partially broken. . . . All these hits were made by 10-inch solid shot, some of them at a distance of not more than from 900 to 1000 yards."

The surgeon's report for the action of September 10th, 1863, in which the Ironsides withstood the cross-fire of forts Sumter and Moultrie for three hours *alone*, gives three men wounded: one slightly in the lip from a splinter from overhead, one in the groin from a splinter coming through the closed port-shutters (not dangerously), and one from a gun-lever—the latter not due to any effect of shot.

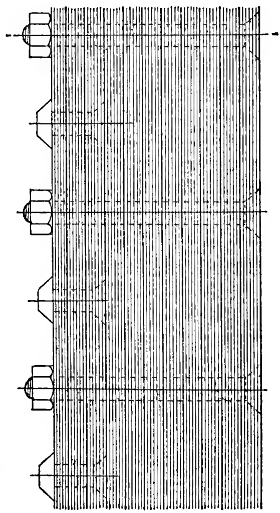
These reports give all the injuries received by the New Ironsides worthy of mention. In a period of about six months she was struck 193 times, and was never forced to go into a home port or depend upon outside assistance for repairs. There appear to have been but two points of weakness about her: 1st, her port-shutters, which on two occasions were shot away; 2d, the fastenings of her deck-plating, which were liable to be driven through. Before analyzing the record of the Ironsides it will be well to examine those of the other armored types.

As mention has been made of the fact that the keel of an ironclad turreted vessel was laid in England before the design of the Monitor had been accepted, it seems proper before describing this ship to state the claims made to originality. In 1862 John Ericsson filed a document in the Navy Department, enclosing an extract from a letter written by him in 1854 to the Emperor Napoleon III., submitting the design of a low freeboard vessel with an armored deck and armored revolving turret or dome. It was from this design that the one of the Monitor sprang. This proves quite conclusively that Ericsson and Coles were close together in their ideas, and it is unquestionable that each worked independently of the other. There is no record prior to 1855 to show the submission of ideas publicly by Coles to any government, so that to Ericsson belongs the priority of design. In 1855 Coles constructed a small turreted vessel for the British government called the Lady Nancy, which did service in the Crimea. To him therefore belongs the credit of floating the first turreted vessel, although the turret of this little craft was not a revolving one, as she was intended to fight bows on. To Ericsson again belongs the credit of getting afloat the first revolving turreted vessel, whose drawback was that she was in no sense a sea-going ship, and to Coles belongs the honor of laying down the keel of a vessel with a revolving turret first, and of launching the first sea-going turreted ironclad. Of the two ships the record of the Rolf Krake must take precedence of that of the Monitor. The latter vessel fought one indecisive action (indecisive through no fault of ship or crew, as has been shown), engaged in one or two indecisive actions with fortifications and sank on her second sea-voyage. The former ship was never in close action with an armored vessel, but she silenced Prussian batteries several times, held the whole Prussian fleet in check in 1864, and after many years of thorough sea-cruising service she is still on the active list of the Danish navy.

The Monitor was a very small vessel, of not much over 1300 tons displacement, having a freeboard of not more than 18 inches, a single turret mounting two 11 inch guns, and a pilot-house near the bow, which cut off the direct forward fire completely. Her hull was of iron, the armored belt, taken in connection with the deck, being practically a separate structure, like the cover of a box, put over the top of the hull proper and riveted to it. Vertical brackets were riveted to the skin, between which the inner layer of backing was secured by bolting through the webs; the outer layer of backing was bolted to the inner layer, and the armor, made up of five 1 inch plates, tapering at



Passaic Side Armor.



Passaic Turret Armor.

the bottom to three plates, was *blunt-bolted* to the backing, the inner end of the bolt coming about two inches short of the inner surface of the backing. The deck-plating was of two ½ inch plates laid over 6 inch planking. Total thickness of backing, 23 inches. The turret had no backing whatever, being made up of eleven thicknesses of 1 inch plates. The three inner thicknesses were riveted together, breaking joints, and forming in this manner a core, to which the outer

plates were attached by through-bolts with countersunk heads, setting up with nuts on the inside. This was the general system of armor attachment followed in all the Monitor type of vessels.

In so far as the record of endurance against the effects of guns is concerned, the ironclads of the Passaic class furnish the best examples. These vessels were built next after the original Monitor, the main differences being that the displacement was increased to 1875 tons, the pilot-house was transferred to the top of the turret and made on the same principle as that structure, the thickness being a scant 7 inches; the turret itself was increased in size to accommodate 15 inch guns; the thickness of armor and method of attachment were, however, unchanged. Of this class of vessels, the Catskill, Montauk, Lehigh, Passaic, Nahant, Patapsco, Weehawken, and Nantucket were engaged in the attempts to overcome the Charleston forts, and the effects of the projectiles on their armor is directly comparable with those of the New Ironsides, which passed through the same ordeal.

The first valuable record on the subject appears in a report made by Rear-Admiral Dupont to the Navy Department with regard to the effect of heavy shot on the pilot-house of the Montauk during an attack on Fort McAllister, in which he states: "I allude to the effect of shot on the pilot-house, causing by concussion or percussion the large *nuts* screwed on to the bolts inside to fly off with great violence, wrenching off the end of the bolt itself. They cross the pilot-house and rebound from the opposite side. This renders the pilot-house most dangerous, and if often struck, untenable. . . . We are also preparing a screen of boiler iron to go around the pilot-houses. It may be well to mention that the above effect was produced without the round head of the bolt outside being struck, but by the impact of a shot between the bolts not weighing over a 32 pdr."

Here at once is seen the development of an evil that had been discovered in Europe five or six years before; that had been partially remedied by the English two years before, at the time of the test of the "Committee Target," and that had been fully remedied by the French in adopting the iron woodscrew, which, for application to a pilot-house, would have necessitated the introduction of backing.

A month after this action three of the monitors again attacked Fort McAllister, the Passaic alone being injured. She was struck 34 times —9 times on side-armor, 13 times on deck, 5 times on turret, 2 times on pilot-house, once on roof of turret, and once on the smoke-stack. The turret-armor was uninjured; three bolts in the pilot-house were

broken, a turret-beam of railroad iron was broken, several bolts of the side-plating were broken at one place where several shot struck close together, and the deck-plating was crushed through in several places.

The effects of the forty-minute action under the forts at Charleston are very important, more especially as owing to a difference of opinion between the Navy Department and the commander of the fleet, resulting in the relief of the latter from his command, the lessons which should have been learned at the seat of government by this action were entirely lost, and in the attempt to overpraise the Monitor type and to give to the world a false opinion of their invulnerability, the most patent defects were left unremedied.

On the Passaic, the outside armor was struck fifteen times, with no noticeable damage. The turret was hit ten times; one shot indenting it locally so as to displace one of the 15-inch gun rails and disable the gun; another, a rifle shot, struck the upper edge of the turret, broke all of its eleven plates, and glancing up, struck the pilot-house, canting the structure somewhat and squeezing up its roof so as to leave an opening of about three inches. Captain Drayton's report states: "Several bolt-heads were knocked off and thrown into the pilot-house and turret, and the former might have done serious injury to those inside had they not been stopped by the sheet-iron lining which I had placed there."

On the Weehawken, two or three shot struck the side armor near one place, and so crushed and broke it that the backing was exposed. The deck was pierced once, although the shot did not get through; thirty-six bolts were broken in the turret and a great many in the pilot-house.

On the Montauk, the side armor was hit four times; one shot detaching the entire starboard after section of plating about three-eighths of an inch from the backing.

On the Nantucket, one rifle shot striking the turret near a port, bulged in the armor so as to jam the port-stopper, thus disabling a gun. Several bolts of the turret were broken, and falling down inside the screen, jammed the turret. The side armor was struck nine times, starting the armor off the backing.

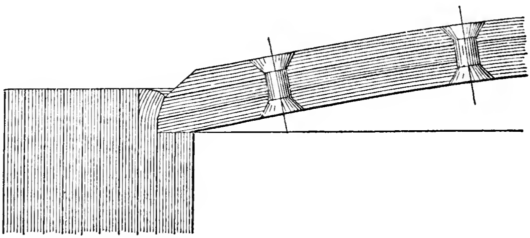
On the Nahant, the bolt-nuts flying from the inside of the pilot-house, disabled the pilot and mortally wounded the helmsman, disabling the steering gear at the same time. In addition to these, five men in the turret were disabled by flying bolt-nuts. The side armor was badly broken in several places, and in others, started off the

backing. Fifty-six turret bolts were broken, some being driven entirely *out* and falling on deck. One shot on the pilot-house broke through every plate.

It was in this action that the Keokuk, a new description of armored vessel, thinly clad, was pierced nineteen times at the water-line and sunk.

On July 10th the Catskill attacked Fort Wagner alone, and in the action was struck sixty times. The deck was broken through in four places, two of the holes requiring shot-plugs to keep out the water. One shot on the pilot-house broke several bolts and drove one nut completely through the ½-inch lining. The side plates on the port quarter were completely shattered from one 10-inch shot.

On August 17th in the general attack on Wagner and Sumter the Catskill was hit thirteen times. One shot struck the top of the pilot-house, fracturing the outer plate and tearing off an irregular piece of



Monadnock.—Roof of Pilot House.

the inside plate about one foot square, forcing out several rivets, pieces of which struck and instantly killed the captain and the paymaster, and wounded the pilot and another officer.

On September 9th three men on the Weehawken were wounded in the turret by a shot breaking one of the railroad iron beams of the roof. A few days before, a shot striking the base of the turret of the same ship, disabled Fleet Captain Badger. The report of the inspector of ironclads of the injuries received by the monitors in the attack of the 17th of August, states:

Catskill.—Piece of pilot-house roof about eight square inches broken in. Twelve bolts broken in pilot-house, fifteen bolts broken in turret, five breaks through the deck, side armor started off in several places. Weehawken.—Deck plates broken through in six places. Fifty

turret bolts broken. Two T beams of turret-roof broken. Twelve pilot-house bolts broken. Side-plating started off in several places, some of the shots penetrating the five plates. The plating at the bow started off the backing four inches. *One shot under the overhang which broke through the side.* Sixteen days necessary to complete repairs on this ship. Patapsco.—Two deck plates broken clear through. Two T beams of turret-roof broken. Twelve days required to repair the ship.

The injuries received by the Lehigh in the course of one month were: one shot within eight inches of the bow, on the port side, which opened the stem from one to four inches, starting four bolts, warping the whole bow and opening the armor on both sides. One shot, some distance farther aft, penetrating four plates and driving the fifth into the backing, starting the deck plates and knocking out nine bolts. The backing was penetrated about five inches, starting a bad leak. Three shot abreast the turret on the side-armor started all the plates in the vicinity. Side-armor around the stern badly started. One shot on the turret bent all the plates, cutting through the outer one and cracking the inner one.

The other actions of the monitors with the forts show practically the same results. No test could have been more severe, nor was it to be expected that the monitor would prove perfect in resisting power; but a simple rehearsal of the injuries sustained should have suggested simple remedies to those having charge of the construction and repair of these ships. This, however, was not the case, for the faults found in this first type were perpetuated in monitors built long after the first actions developed their existence. The fastenings of the side-armor showed their liability to draw from the first, and the trouble was one that could have been remedied without withdrawing the ships from service. Even had this not been the case, the blunt-bolt should have been condemned, yet it never was. The danger of using interior nuts on ordinary screw-bolts was demonstrated in the first action of the Passaic, and whilst iron screens might have served as a partial cure for the monitors then engaged at the front, certainly the evil should have been cured in other vessels. Attempts were made to remedy this fault, it is true, but they were ineffective, and these attempts were inexcusable in the face of the improvements already cited as made by Sir William Palliser in reducing the shank of the bolt, and by the Committee on Iron Defences (English) in introducing rubber washers. The roofs of the turret and pilot-house were repeatedly proved to be dangerous, yet the faults were not remedied.

In fact, so great was the glamor cast over the monitor type of ships by the defeat of the Merrimac and the name of Ericsson, that although steering-gear was deranged and turrets were jammed in every general action, the spindle-turret with its pilot-house mounted on top was retained unaltered even in the monitors rebuilt in 1874. It cannot be claimed that the great demands in other directions left no time to examine into these defects and remedy them, for the construction and development of the monitor type was entrusted to a special body of officers; furthermore, an officer charged specially with the inspection of these vessels before Charleston was kept constantly at the front.

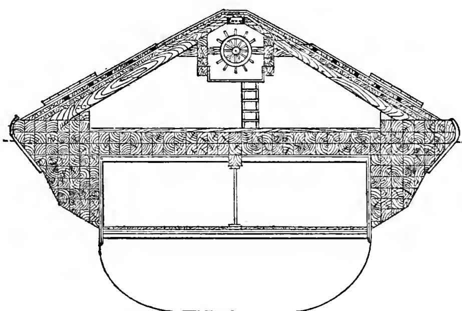
The following extract from an official report made by one of these officers just after the action of April 7, 1863, shows clearly the absolute blindness to any and all imperfections of the monitor:

"When the laminated plates upon the side of the monitors were struck severely, the indentations were deep, the bolts securing them to the backing started loose, the entire plates bent and separated from each other to an extent which impressed the non-professional observer with the idea of great injury; but when the [expert] examined them with a view of judging how well they would withstand another blow of the same force upon precisely the same place, he perceived that the original power to resist shot had not been greatly reduced. On the other hand, the *solid* plates of the Ironsides were not so deeply indented; there appeared to be no disturbance of the plates by bending, but few bolts were started, and few persons other than the critical [expert] could look closely enough to see that the plate was entirely broken through in a manner which would inevitably permit the passage of the second shot striking the same place. To the casual observer, therefore, the solid plates will have the appearance of having withstood the bombardment better than the laminated; but the *unprejudiced* [expert] will perceive that the latter disposition of the metal is much the most effective in attaining the desired end."

In view of the fact that as early as 1854 it had been definitely determined that laminated armor only possessed two-thirds the resisting power of solid plates of the same thickness; that the New Ironsides of all the ships engaged in the action of April 7th, was the only one in condition to go into action again immediately; that after hauling out of action she was submitted to weeks of twisting strain through rolling and pitching at her station outside of the bar, which would have developed any weakness brought about by the impact of projectiles, the above expert opinion seems to lack decidedly in the ele-

ment of fair-mindedness. Instead of regarding the action as a test of the weak points of all the ships engaged, which were to be singled out, studied and *remedied*, there was a demand—not only implied, but expressed, in official language and the most positive terms—that the shortcomings of the monitors should not be made known, *in order not to give encouragement to the rebels.* In obedience to this these serious faults were belittled, and so the Monitor, born in battle in the United States, never passed the age of swaddling-clothes here, while in Europe it developed into the Inflexible and Duilio of to-day. As for the New Ironsides, not only was her record neglected, but no attempt was ever made to either repeat her type or develop her. The nearest approach to it was made in the Dunderburg, which far more closely resembled the Tennessee than the New Ironsides.

The attempts made in the South to create an ironclad navy were by no means contemptible. With the limited means at hand and the lack of skilled labor available, the results call for the admiration of naval people. The general type is well represented in the Atlanta and the Tennessee. The former of these vessels was converted from



Midship Section of Atlanta.

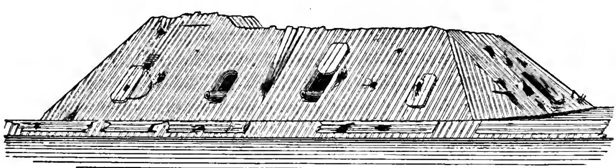
an iron-hulled blockade-running steamer; the latter was a wooden-hulled ship, built for the purpose. In both, the battery was carried in a central citadel, whose walls sloped at the sharp angle of 30° with the horizontal. The solution of the problem of converting the blockade-runner Fingal into the ironclad ram Atlanta was of the simplest form. The additional displacement required to float the superstructure being known, a raft of logging of the required size was laid over

the hull, sloped down to the natural water-line of the vessel and covered with ½ inch plates. At the knuckle of the casemate, which formed the water-line, 2 inch plates were bolted, and the sides of the casemate proper consisted of 15 inches of Georgia pine logging, covered by 3 inches of oak, on which were two layers of 2 inch iron bars 7 inches wide (probably rolled from railroad iron). The inner layer was horizontal and the outer one was vertical, the fastenings being 1¼ inch through-bolts set up with nuts and washers.

In her action with the Weehawken she was hit four times; first by a 15 inch shot on the side of the casemate, on a line with the port-holes, breaking completely through armor and backing. The shot itself did not pass through, but the splinters (aggravated in this case by the soft pine of the inner backing) wounded upwards of forty men. A second shot (supposed to be an 11 inch) struck a port-shutter, breaking it and indenting the armor beneath. A third shot struck the pilot-house, broke the heavy *casting* of which it was made and displaced several plates below it, breaking and indenting them. The fourth shot struck the knuckle about amidships, breaking the plate and displacing several others.

The armor and backing of the Tennessee were of the same description as those of the Atlanta, being somewhat heavier. The framing of the casemate consisted of an inside diagonal ceiling of 2½ inch oak, vertical pine timbers 13 inches thick, yellow pine planking 5½ inches thick, an outside layer of 4 inch oak timber, and the armor, made up of three thicknesses of 2 inch iron bars 7 inches wide—the whole fastened by 1½ inch through-bolts, set up with nuts on the inside. The armor of the ends of the casemate was one inch less in thickness, the outer layer of bars being 1 inch. Total thickness of armor on side of casemate, 6 inches of iron and 25 inches of backing.

In her action with Farragut's fleet in Mobile Bay she received the following injuries from projectiles: After side of casemate nearly all the plating started; one bolt driven in; several nuts



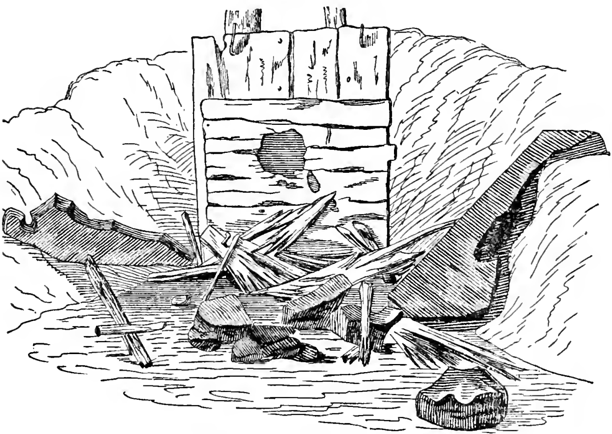
Casemate of "Tennessee."

knocked off inside; marks of nine 11-inch solid shot in the close vicinity of the port. Port side of casemate, a hole completely through the side made by a 15-inch shot, leaving on the inside an undetached mass of oak three feet by four projecting inside the casemate about two feet from the side, shot not through. Marks visible of between forty and fifty shot, varying from severe to slight. Smoke-stack shot away. Three port-shutters jammed while closed, disabling the guns behind them.

The effects of projectiles on these two vessels appear to show quite distinctly a line of demarcation between the powers of the 11-inch and 15-inch guns; that is, the armor of the Atlanta was enough to thoroughly resist the 11-inch projectile with the 20-pound charge at 500 yards, and that of the Tennessee to withstand the same shot practically at the muzzle. The 15-inch shot broke through completely in both cases. Here, as elsewhere, the total unfitness of the plain armor bolt appears, the nuts flying off almost invariably. The system of exterior port-shutters, forming in reality a part of the armor, failed in both these vessels and also in the Ironsides. Pine backing was proved not only to be useless in resisting power, but a source of positive danger from flying splinters. The iron bars used as armor showed their weakness in the ease with which they were displaced. This disposition was not one of choice, however, as material was lacking for the manufacture of either solid or laminated plate.

A great number of experiments with the 11-inch gun against armor were made at Washington during the war, some of which were especially valuable in elucidating points with regard to the composition of armor. The charge used was thirty pounds of powder with the solid shot of 168 pounds, giving a muzzle energy of about 2750 foot-tons. As an evidence of the variable quality of plates which were manufactured at that time, and also of the error in claiming too hastily great racking power for a gun, two experiments are chosen which were made, the one against what was known as the Dahlgren target and the other as the Nashua target.

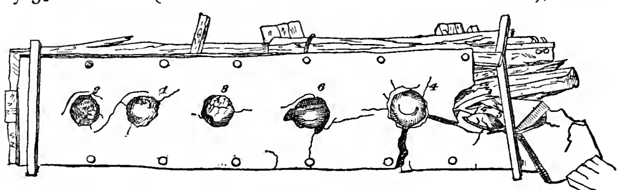
The Dahlgren target was a single 4½-inch plate, eight feet long by four feet wide, backed by twenty inches of white oak and a 1-inch skin. Against this were fired two 11-inch shot, one 68-pdr. shot and one 40-pdr. rifle steel shot. The plate was secured to the backing with the plain bolt and nut. These four shot smashed the plate to pieces and brought it down entirely from the target together



4½-in. Dahlgren target.

with a great part of the backing; the last shot, which was an 11-inch, going entirely through.

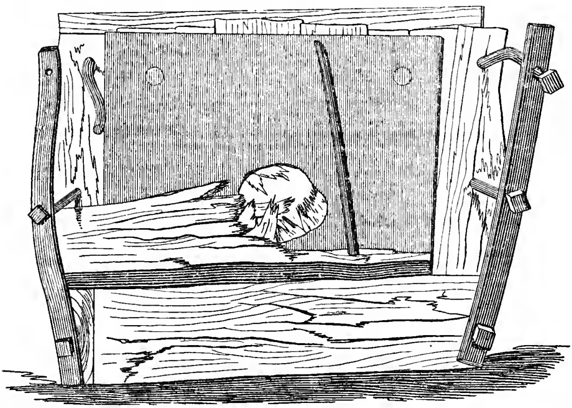
The Nashua target consisted of a single 4½-inch plate, 16 feet long by 3½ feet wide (manufactured at the Nashua Iron Works), backed



Nashua Target.

in the same manner as the Dahlgren target with twenty inches of oak and a 1-inch iron skin. Against this were fired at a range of thirty yards three 11-inch cast-iron shot and three wrought-iron ones. The plate was badly cracked in some places and the fifth shot broke off one end of it. In no case, however, did a shot get entirely through the target. The cast-iron ones were broken up and the wrought-iron ones did not penetrate a full diameter. An inspection of these targets shows at once that the plate used on the Dahlgren target was a

very poor one and therefore gave no true evidence of the power of the gun. The Nashua target, on the other hand, showed quite conclusively that the 11-inch gun at point-blank range was not equal to the task of overcoming a good 4½-inch plate backed by twenty inches of oak. The combination was as close to the limit of power of that gun as could well be made. The experiment further showed that no ship armed with 11-inch smoothbores and cast-iron projectiles could be considered a match for the Gloire class of ironclads. This was no light matter when it is considered that the New Ironsides was the only vessel rated as a frigate carrying these guns owned by the government, whilst the Normandie, impregnable to her battery, watched the course of the war from a Mexican port.



Wood-screws and Through-bolts.

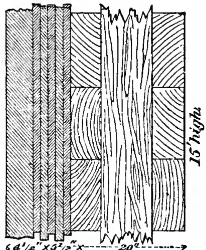
Another experiment shows in an excellent manner the comparative value of the wood screw and the plain bolt and nut. A 4½-inch plate was backed with twenty inches of oak and *faced* with twelve inches oak. The plate was held to the backing by four iron wood screws, whilst the facing was secured to the backing by six plain bolts set up with nuts. The single 15-inch shot fired against it pierced the target completely, tearing off the facing and starting the backing. *None of the wood screws were either broken or started from the face of the plate.* All of the plain bolts, however, were started, one bolt-head was broken off and one bolt-nut with the threaded end of the bolt

was torn off. The racking effect gave the woodscrews a very severe test, for one piece of plate was thrown over one hundred feet *to the front* of the target.

Quite a long series of experiments was carried on against plates with sheets of rubber varying in thickness from ½ inch to one inch applied in various ways, as facing to plates, between the layers of laminated plating and between plate and backing, but in all cases it was found to have no effect whatever in relieving the plate. Before leaving the 11-inch gun certain experiments carried on in France and Russia are well worth recording as showing the maximum effect attainable with a 168-pound spherical projectile. A target was built at Gavres representing a section of the Flandre class of ironclads, consisting of a 4¾-inch Petin and Gaudet plate, backed by twenty-seven inches of teak and oak, the whole secured by iron woodscrews. Against this during the trials were fired first a steel 168-pound ball with 50 pounds of powder, the gun used being an 11-inch rifle, whose great length of bore permitted a complete utilization of the charge. The shot went clear through the target and to spare. A second steel shot, fired with a charge of only 22½ pounds of powder, also went through and to spare.

This experiment was partially verified at St. Petersburg, where steel 168-pound projectiles were fired from an 11-inch rifle at a 4¾-inch plate backed by twenty-four inches of oak. The shot pierced the target first with a 33-pound charge and again with one of 27½ pounds. Comparing these shots with the ones fired at the Nashua target a good idea is presented of the different effects produced by partial and complete utilization of the energy of fired gunpowder. The cast-iron shot broke up, barely breaking through the 4½-inch plate and making no noteworthy cracks. The wrought-iron shot passed through the plate, but was held by the backing of twenty inches. The steel shot, fired from a gun that fully utilized the full charge of powder, showed its capability of piercing 4¾-inch plates and 27-inch backing with a charge of powder 7½ pounds less than that required for the cast and wrought shot in the American gun.

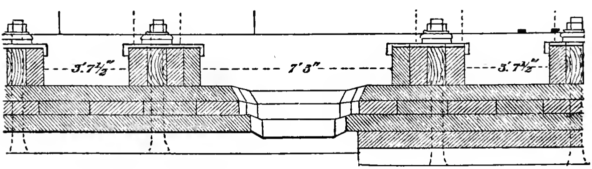
The 4½-inch plate, with 20-inch backing, proved to be no match at all for the 15-inch projectile, and in one experiment at Washington a shot broke through a 6-inch Petin and Gaudet plate with 30 inches of backing at a range of fifty yards with sixty pounds of powder, the muzzle energy being about 6100 foot-tons. A 4½-inch plate backed by 5½ inches of 1.1-inch plates, behind which was twenty



Section of 10-in. target.

inches of oak, proved too much for this projectile, however. A shot fired at it broke out a disk of the 4½-inch plate and the thin plates were indented though not broken through. Nearly all the bolts, however, were either thrown out or broken from the shock. By far the most instructive experiments carried on with 15-inch projectiles were made in England in 1868 with a Rodman 15-inch gun, using American cast-iron shot and English powder.

The object of the experiments was to test different combinations of armor for fortifications, and the guns used during the trial were the 12, 10, 9 and 7-inch Woolwich rifles and a 15-inch Rodman smooth-bore. The charge of the Rodman gun was 83 pounds of English R. L. G. powder, which corresponded in effect to 100 pounds of American Mammoth. The projectile was 452 pounds American charcoal cast-iron. The muzzle energy was 5700 foot-tons. The

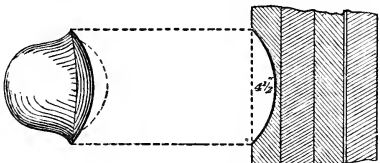


Bermuda Target.

first target against which the 15-inch gun was fired represented an embrasure section of a proposed fortification for Bermuda, consisting of three thicknesses of 5-inch plates on one side of the embrasure and four thicknesses on the other side. Between the inner and the middle plates was inserted a single thickness of leather of ⅜ of an

inch; otherwise the plates lay directly against each other and were through fastened with Palliser bolts.

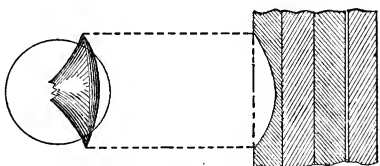
The first shot of the smoothbore was against the 20-inch side of the armor, the projectile striking the ground a little in advance of the target, thus hitting the armor on ricochet. The shot was deformed, but not broken; penetration 4½ inches; two cracks in the outer plate; no signs of damage on the interior of the casemate. The second



15 in.-Shot- 20 in.-Armor.

shot struck the plate fair; projectile penetrated 4½ inches and broke up. The main piece of the shot which was mushroom shaped rebounded some distance; outer plate cracked through, the crack running from the point of impact to the edge of the plate. On the interior the supports were slightly started.

The third shot was on the 15-inch section and struck the plate fair. Projectile deformed but not broken; penetration, seven inches; diameter of imprint, seventeen inches. This greater penetration was due to the shot striking near the edge of the plate, so near as to start out the

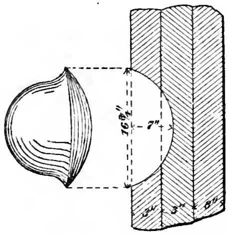


15 in.-Shot- 20 in-Armor.

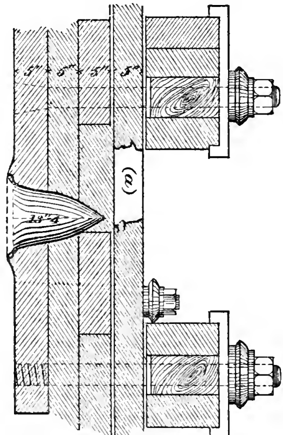
lower edge of the next plate above; one bolt broken. The fourth shot, against the same section; projectile broke up and pieces thrown back; penetration five and a half inches, one bolt driven partially in, and the outer plate split diagonally across. The fifth shot struck the granite block foundation, completely smashing the block hit.

Two shots were fired at this target from the 10-inch Woolwich rifle, which furnish an excellent comparison of the relative powers of the

two guns. The charge of powder was sixty pounds, weight of projectile 397 pounds, muzzle energy 4580 foot-tons. The first shot hit on the 15-inch section and pierced it; the outer plate was cracked across and a large piece of it was thrown down from the target. The second shot struck the 20-inch section, penetrating thirteeen inches, and



15 in. Shot–15 in. Armor.

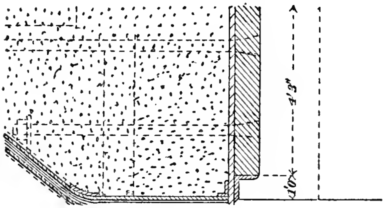


10 in.–Rifle.–20 in.–Armor.

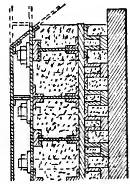
cracked the front plate. The shot broke up, the head resting in the hole, the rest being thrown back. The inner plate of the armor was broken and a piece five feet long by sixteen inches wide (*a*) was thrown into the casemate. Some of the supports were badly bent and racked. Against this solid target then, the 10-inch rifle showed *greater racking effect* and far more penetrating power than the 15-inch. In the official summary of these experiments the following very significant remark is made: "The target of the Plymouth Breakwater and Bermuda Forts resists successfully the most powerful smoothbore."

A second target against which the 15-inch gun was tried, consisted of an 8-inch plate backed by a 2-inch plate resting against a cement backing eight feet thick, the whole fastened by through bolts ten feet long. One shot fired against this broke up on impact; penetration four and one-third inches, no interior effect visible. Still another target was tried with this gun, consisting of a 6-inch plate

placed against U frames seven inches deep, filled with Portland cement; these frames riveted to a 2-inch plate backed with cement fifteen inches thick. A shot fired against this was deformed but not



15 in. Gun - 8 in. Plate.



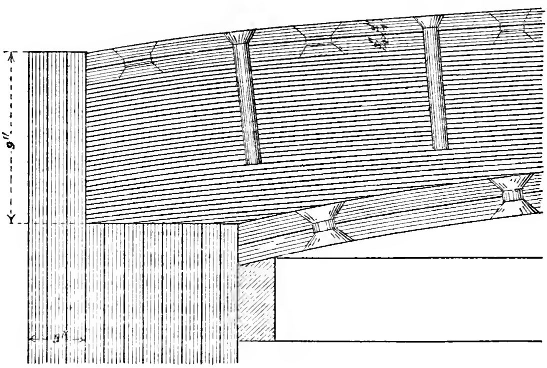
15 in.- Gun. - 6 in. - Plate.

broken; penetration 7.7 inches; bolt broken just above the point of impact; inside plate somewhat sprung; all the rivets broken. One more target consisting of a single 15-inch rolled plate unbacked, was fired against; the penetration being four inches. The plate was broken, showing an inferior quality. In the final report on these experiments it was stated that the 12 and 10-inch rifles were more than a match for the targets; the 9-inch rifle was almost powerful enough. The 15-inch spherical projectiles do not penetrate enough to do serious damage, but at a close range (200 yards) cracked the plates considerably.

This series of experiments was the last one in which a 15-inch gun was brought against armor; the test was a perfectly fair competition, and the inferiority of the highest calibred smoothbore used afloat was clearly demonstrated. In reality, the 9-inch Woolwich did more actual damage than the 15-inch Rodman, but the best comparison in effect is shown with the 10-inch rifle. In so far as weight of gun and ammunition is concerned, which is an important element in naval artillery, the 10-inch possesses great advantages. Taking for example, the ordnance allowance for one of the single turreted monitors, which could be fairly taken at two 15-inch guns with eighty rounds of ammunition. By substituting guns corresponding to the 10-inch Woolwich, a more effective battery would have been given to the vessel, whilst a saving in weight of about eight and a half tons would have been realized. From the examples given of the effects of the 11 and 15-inch, it clearly appears that the great racking effects claimed for these guns were never realized, *except when they were*

brought to bear on inferior iron plates. In 1863 the manufacture of the 4½-inch plate in the United States had been so far developed that it could not be split and broken up by the 11-inch projectile. The Shoeburyness experiments of 1868 showed that at that date the same was true of the 5 and 6-inch plates opposed to the 15-inch gun. From this time there could be no question of overcoming iron armor except by punching it.

The important part which the fastenings and the backing play in the development of armor was thoroughly brought out in the fights between the monitors and the Charleston forts, and yet, notwithstanding the superiority in effect shown by the rifle-shots fired against the monitors, when compared with those of the 10 inch spherical projectiles, the Parrott rifle was left undeveloped and the monitor-armor almost entirely unimproved. Almost the only radical change made



Roof of Pilot House.—Modified.

in the armor of these vessels was that of increasing the thickness of the pilot-house and turrets (which had never been pierced), and after the death of Captain Rodgers had forced those in charge of the construction of the monitors to acknowledge one defect, an alteration in the roof of the pilot-house by covering the original two 1 inch plates with 8 inches of wood, over which was laid two ¾ inch plates. The extra plates on the cylinder of the pilot-house were carried up to the top of the outer plates. This modification may appear at first sight

to be an improvement, but in reality it was not, for the three plates carried up were easily penetrable by both spherical and rifle projectiles, which thus attacked the wood backing in its most vulnerable direction, so that the chances were in favor of tearing off all the wood and the outer plates by one or two shots. In arranging the fastenings a singular and very bad error was committed. One half of the bolts securing the outer plates to the backing were blunt-ended, plain bolts like those of the side-armor, ending about two inches short of the inside of the backing. These were of no use whatever in holding against a shot coming in at right angles to them. The other half of the bolts went clear through and were either upset at the inner end or set up with nuts, either of which disposition left the interior of the pilot-house in as bad a condition as ever, in so far as the danger from flying bits of iron was concerned. A much better disposition would have been: 1st. To house the outer edge of the whole roof behind the full thickness of the pilot-house armor. 2d. To put wood-screws through the upper part of the armor to a depth of a foot or more into the backing, at right angles to the face of the armor. 3d. To tie the outer roof-plates to the backing by short wood-screws. If, in addition to this, single 2 inch plates had replaced the two inner thicknesses, the rivets used here would have been avoided and the roof would have been cured of its defects.

Before leaving the smoothbore gun, attention must be called to one vital fault, which was an almost insurmountable obstacle to development. The difference in effect between cast, wrought and steel projectiles has been shown. Wrought-iron shot had to be forged necessarily, and the same operation was required with steel ones in order to give them the necessary strength to resist deformation or breaking. To forge a spherical projectile with the accuracy of outline demanded in shot is a matter of the greatest difficulty, increasing the cost of the ammunition beyond the point where the resulting effects would warrant the expenditure. This point was made the subject of investigation in England in comparing rifled and spherical projectiles, and the report stated that cast iron was the only metal that could be used with smoothbores without extravagant expenditure. The use of this metal in projectiles appeared to show a limit in effectiveness beyond which no increase of calibre would be of benefit, and it was thought that the 13-inch projectile was at the limit. That is, having given an armor which would not give way to the 13-inch cast-iron projectile, it would be equally efficient against a 20-inch

cast-iron shot. The additional energy of the latter would practically go for nothing, as it would be carried away from the armor in the rebounding pieces of shot. It is true that many of the cast-iron projectiles made of the best American charcoal iron did not break on impact, but this was the exception rather than the rule, and even then, where the armor plates were solidly backed the difference in effect was not great.

In thus condemning the 15-inch smoothbore, it is not intended to convey the impression that the gun is a useless one or that during the civil war it was not a thoroughly effective piece of ordnance. As used against the Charleston forts and the Confederate ironclads, no guns then in existence could have served the purpose better, for the opposing armor and stone walls were inferior in resisting power, whilst the guns were frequently used against troops in the field and lines of earthworks where the shell-fire was terribly effective. It required no great foresight, however, to see that the armor carried by men-of-war would be rapidly developed; therefore, the rifle gun must absolutely replace the smoothbore in coast fortifications. The Civil War gave to naval vessels a peculiar line of duty which would not be realized in any foreign war, which, from the geographical position of the country, must be eminently a naval one. The 15-inch smoothbore represented the maximum development of that type of artillery, whilst its companion piece of the monitors, the 100-pdr. Parrott rifle, was but the commencement of a new development. The great error of the artillerist in America was the neglect to cultivate the rifle and develop its power, whilst on the armor side, those in charge of the work closed their eyes obstinately to the invaluable lessons taught by the Charleston actions. There was but one natural result to these follies, and to-day the United States, after receiving the most valuable experience possible, at the time when in the early development such experience was worth the most, finds itself without guns and without armor equal to cope with the guns and armor in use in Europe at the close of our Civil War.

This total lack of development of armor, or neglect to profit by the experience of actual war, assisted by the evidence of results obtained on foreign firing-grounds, is a matter of reproach which must be borne by the navy; and yet, of all those who were interested in or connected with the question of armor for naval use, none are less blamable than those who were actually engaged in battle on board of the monitors. The reports and official letters of command-

ing officers teem with information with regard to the faults and with wise suggestions of remedies. The ingenuity of subordinate officers was put to the severest test to neutralize the bad effects of faulty dispositions, and they accomplished marvellous results. Indeed, the Navy Department called for especial reports from the commanders of the ironclads before Charleston, which should detail the faults and suggest remedies. Amongst the reports made in response to this call, one, made by Lieutenant Commander (now Commodore) Edward Simpson, has a more than ordinary interest, not only from the thorough detail of the faults, and wisdom of its suggestions, but from the fact that apparently not the slightest attention was ever paid to it.

With regard to the side-armor of the monitors, Captain Simpson says: "The side-armor, as disposed on the overhang of these vessels, does not perfectly fulfil the requirements. A shot of any size never strikes it without producing more or less serious effect, sometimes breaking through all the plates, generally driving the mass of iron before it into the backing, and sometimes causing leaks. The solid plates of hammered iron on the New Ironsides, though only 4½ inches in thickness, resist the impact of shot much better than the 5 inches of laminated iron on the sides of the monitors. . . . The manner in which this armor is arranged at the stem is very insecure. These vessels are useless as rams, except against wooden vessels. The armor of this vessel at the stem is sprung apart 6 inches by contact with another monitor while in the act of turning. The laminated iron, when disposed in a plane perpendicular to the flight of the projectile, does not seem to answer all demands; but when disposed in the form of a turret, no objection can be raised to it. The turrets are as near impregnable as anything can be made. The only objection to them is the 'through-bolts,' which allow the nut inside to fly when the head of the bolt is struck.

"The most vital and dangerous part of this construction is the roof of the turret, which must be apparent to every one as weak. It never can be struck without causing damage. . . . The roof of the Weehawken was struck at long range; the result was the fracturing of the thigh of one man, and lighter wounds to two others; and this or worse must be the result as long as the roof is left in its present state.

"I will perhaps be excused if I hazard an objection to the principle involved in the present arrangement of turret, pilot-house and spindle.

"The turret has two bearings on the spindle—one on a shoulder, under the centre of the floor-beams, and another (through diagonal braces) from the ends of these beams to another shoulder at the level of the roof. These bearings are provided with composition rings to prevent cutting.

"The pilot-house is supported on the end of the spindle. In order to secure the pilot-house from being knocked off by the effect of a blow, a composition ring is secured to the roof of the turret, which, at its top, has a horizontal flange which overlaps a projecting ring attached to the base of the pilot-house.

"This is the best manner in which the object could be attained, and, as long as the form of all parts remains as they came from the foundry or machine shop, it will work well. But the battering effect of heavy ordnance will knock anything out of shape, even an 11-inch turret or pilot-house, as in the case of this vessel, causing the turret to revolve eccentrically. The effect of this eccentric motion on board of this vessel was the derangement of the whole system by the jamming of a piece of $\frac{7}{8}$-inch bolt between the composition ring and the pilot-house.

"The piece of bolt entered freely at the place where it had stopped in, but the eccentric motion caused the surfaces of ring and pilot-house to approach each other when the turret was revolved, and the jam took place. . . . Efforts were made to force them apart, with 35 pounds of steam, at the risk of destroying the gearing of the turret-engine, and causing the beams of the ship to work several inches; but no effect was produced. . . . This difficulty is most serious in its consequences; the steering gear is of course deranged and the pilot-house becomes useless. It may occur again in this vessel; it may occur on board of any other vessel of this class.

"I recommend that a system of turret should be devised by which it will have no connection with the spindle, but have a bearing all around its base, running on such antifriction rollers as the inexhaustible ingenuity of our mechanics can invent. . . . I would also recommend that the base of the turret should be carried below the spar deck. The base-ring as now attached to the turret prevents injury to the bottom of the turret itself; but the liability of stopping the revolution of the turret by forcing the iron down to the deck-plates is just as great as ever. In a late action of this vessel, owing to this cause, it required at one time 34 pounds of steam to revolve the

turret. . . . I have also had two shots that penetrated the deck directly under this ring."

This report was written in October, 1863. The faults pointed out were ones which had been repeatedly made evident in action, which had been studied and profited by immediately in Europe. The suggestions with regard to the turret made by Captain Simpson were precisely what will be found to-day carried out in every turreted vessel built in Europe, and yet, after this report has been permitted to quietly absorb dust for twenty years, the question is allowed to rise seriously whether this disposition of turret and pilot-house shall be applied to United States turreted vessels. Because a publicity of the faults of the monitors would give encouragement to the rebels, they were allowed to exist uncorrected, and to give to Americans an entirely false idea of the real strength or weakness of these vessels. As a *type*, the monitor is superb; as the ship actually exists in the United States navy it is but a single step short of absolute failure.

IV.

Iron Armor and Rifled Guns.

Although armor and rifled guns have gone hand in hand in development since the time when they were first opposed to each other, neither one depended upon the effects of the other for its creation. Shell-fire from smoothbore guns was introduced into the French naval service in 1824, and at that time General Paixhans, in an official letter to the French government, prophecied that this new departure would force the creation of armored ships. The result of the naval action of Sinope in 1853, when a small Russian squadron armed with shell-guns annihilated a Turkish fleet, was the immediate cause of the introduction of armor, which, two years afterward at Kinburn, neutralized the invention of Paixhans and fulfilled his prophecy.

The naval rifled gun did not appear fairly in service anywhere before 1858, although the principle of the rifle antedated in actual use even the shell-gun. First appearing as the rifled musket in the hands of infantry, it gradually developed into the light field-piece, the siege-gun, and finally heavy naval and fortress artillery. To France, again, is due the credit of the first step in the introduction of naval rifled artillery. During the Crimean war, a number of 16 centimeter (6½ inch) cast-iron rifles were constructed and put aboard ship for trial. Although these guns were crude in the extreme in design, they presented so many points of superiority over smoothbores of corresponding weight, especially when tried against armor, that development was rapid; and, before 1859, the government was thoroughly committed to the rifled gun as the standard for heavy artillery. To follow the details of the development of the various systems of artillery would require a volume in itself, and by far the greater number of the modifications are entirely unconnected with the subject of armor. A concise review of the main steps taken, however, is necessary to a thorough understanding of the effects produced; and a description of the *defects* in development furnishes a study which may be of the greatest use to naval officers, not only in so far as ordnance and armor are concerned, but in every other department of the naval profession.

The first naval rifles constructed in France were cast-iron muzzle-loaders, modelled after the Paixhans shell-guns and having studded projectiles. In 1864 this type was condemned in favor of a cast-iron, hooped, breech-loader. The breech mechanism of this type has remained the same in principle up to the present time, and is now recognized throughout the world as being the most efficient of all the types in use. In this type (known as the model 1864–7), parabolic rifling was introduced; the studded projectile, however, being retained. In 1870 this gun was modified by improving the breech-action, lining the gun with a steel tube on the Parsons plan, altering the rifling to the multigroove system, substituting copper bands on the projectile for the studs, and lengthening the bore. In 1878 this type was again modified, the main alterations being in the substitution of steel for cast iron, and lengthening the bore.

In 1860 France undoubtedly led the world in development. Although not at that time adopted, her systems of breech-loading, polygrooved rifling, increasing twist and banded projectile, were under actual test. The government was thoroughly committed to the complete substitution of rifled for smoothbore guns. With such a lead as this in the race of development there was no reason why that country should not have kept to the front, but two false steps taken threw her to the rear so rapidly that before 1867 both England and Germany were far in advance. Let it be understood that whilst in other countries there was a strong element in favor of the smoothbore, in France that artillery had been condemned definitely throughout the navy and coast fortifications. An immediate and complete substitution was demanded, the cost of which would be enormous. Having boldly taken the stand for a revolution of system, and wisely studied the true line of development, the country itself, and more particularly the artillerists, took fright at the budget. Compromises were sought and found in the conversion of the old smoothbores and the use of cast iron in the new constructions. Once started in this direction, the talent of France struggled gallantly but uselessly to overcome the fatal defects of cast iron. For fifteen years the development of power in artillery was kept at a standstill, except in so far as increase in calibre was concerned. The end was reached in 1875 when cast iron was condemned, and from that time France has brought her artillery rapidly and steadily up until it is again abreast of the foremost systems. The compromise, instead of being an economy, was an absolute waste, as it led to the condemnation of two

distinct systems instead of one; for the heavy cast-iron-lined rifles must be replaced before they have served out a lifetime. In defense of their line of action the French have pleaded the inability of their factories to produce the steel required; but in face of the facts that, from the beginning of armor manufacture, French steel plates have never been excelled, that to-day France is the only country able to produce thick all-steel armor plates, and that she first introduced steel frames and plates into her ironclad construction, such a reason is trivial.

The other great mistake made in this navy was the neglect to develop, or rather nurture, the manufacture of gunpowder. In the early days of rifled guns it had been found that a Belgian powder-making firm at Wetteren produced a most excellent large-grained powder. The supply of this material for naval use was given over entirely to this firm, thus removing from those who were developing the gun, the responsibility for the development of the powder. It is only within the past six years, or since the introduction of the all-steel rifle, that the manufacture of special powders for heavy naval guns has been systematically established in France.

In England, in 1855, Armstrong constructed his first breech-loaders, which were introduced into the field artillery service. About the same time the Blakeley system of hooped cast-iron muzzle-loaders (the original of the French hooped guns) was experimented with; and shortly afterward Whitworth submitted to the government his types of breech and muzzle-loaders. In 1858 and 1859 a series of competitive tests against armor was carried on between the Armstrong and Whitworth systems, resulting in the adoption of the former type for the navy. The type of breech mechanism of this gun was, however, fatally defective, and the moment that the calibre of the gun was carried to the 7-inch, which was the size required for the main batteries of all unarmored vessels, the faults became plainly apparent. After repeated accidents and much loss of life the navy clamored for a muzzle-loader. A special committee on designs for artillery was established in 1863, and after a series of exhaustive experiments the Woolwich type of muzzle-loader was adopted in 1864. This consisted of the Amstrong coiled principle of construction combined with the French groove and studded projectile. The rapidity of development in calibre was astonishing. Commencing with the 64-pdr. in 1864, the 7-inch and 9-inch appeared in 1865, the 11-inch in 1867, the 12½-inch in 1875, and the 16-inch in 1877. As early as 1864

Armstrong constructed a 12-inch, which was immediately copied and improved upon at Woolwich. The limit of development was reached in 1877 with the 16-inch by the government and the 17-inch by Armstrong. In a single year the most complete change took place, and from the steel-tubed, coiled wrought-iron muzzle-loader, the naval weapon was altered to the long-bored, all-steel breech-loader, which is the type now being developed.

The first false step taken in the English development was in the substitution of the muzzle for the breech-loader. At the time when this was done the error was excusable, for notwithstanding the success attending the French and Prussian systems, both of these types were weak and untrustworthy, and the navy had been made suspicious of all breech mechanisms through the faults of the Armstrong. The Woolwich system undoubtedly gave the strongest type of gun then in existence, and this quality, which is the main one to be secured in any artillery system, gave to those guns a reputation which, however well deserved at first, became a stumbling-block to development in the end. Up to 1868 the Woolwich gun had no equal, but English artillerists are alone to blame for the ground lost between 1868 and 1878, that sent their guns from the foremost rank to the rear in everything except diameter of bore, which in development is the last step for consideration. In the light of the rapid strides being made, not only all around them, but in England itself, English artillerists could not possibly have placed themselves in a more ridiculous position than they did in their attempts to hold against the irresistible tide of development. For years it was known to them that the studded system of projectiles caused the cracking of the tubes. Absolutely driven from their argument of poor steel, they accepted the gas-check on the rear of the projectile with the apology that it was necessary to save the powder-gas lost through the windage-ring. Again it required years of test with the gas-check to force them to acknowledge that with it the stud was an unnecessary incumbrance. The inventive genius of all England was put to a strain in enlarging the chambers of the muzzle-loaders and contriving novel cartridges before it was acknowledged that the only possible way of getting a large charge home in a gun was to put it through the breech. When at length the complete change was forced, the new guns hitched along from coiled wrought-iron jackets to coiled steel, from coiled steel to mild steel forgings, and finally to the jacket of full strength. The length of gun went from 18 to 22 calibres, then to 25, again to 28, and apparently with reluctance to 30 and over.

Had all these steps been advances in general development they would have been proper, but they were not. Every single change from the original Woolwich to the present steel breech-loader was made only after it had become an old story on the continent. When the Krupp breech-loader overpowered the Woolwich gun at Tegel in 1868, the English obstinately closed their eyes to the lessons of the long bore, high charge, prismatic powder and tight-fitting projectile, and nothing was heard but complaints of an unfair test. Breech-loading, instead of being examined carefully by the lights thrown upon it on the continent, was sneered at as being "Frenchy." Steel was condemned at Woolwich apparently more because Krupp was a successful rival of Armstrong than for any other reason.

In Prussia, the breech-loading rifle was adopted in 1858, the guns being of cast iron, with a breech mechanism modified from the Wahrendorff type and called the Kreiner double wedge block. In 1864 cast iron was condemned as being entirely unfit for rifle construction. At this date there was much discussion over the type of breech-block, the Navy Department demanding the Krupp cylindro-prismatic block, whilst the Artillery Board insisted upon developing the Kreiner type. The Navy at this time also protested against the use of both cast- and wrought-iron projectiles. In 1866 the Navy Department ordered four 8½-inch Krupp guns for trial, and the excellent results given by the tests caused the adoption of the gun for both marine and coast artillery. From that time to the present, the development has been so regular and steady, that though the Krupp gun of to-day is very different from the model of 1866, there is no period where a distinct line marking a change is apparent. The single change of system was made in 1866, and that was not a radical one. Choosing at the start the best of the metals, the Krupp type has in reality proved to be the least expensive of all. The substitution of new guns for old goes on with true Prussian precision. As the new guns go into the most prominent forts and ships, the older patterns retreat into those of lesser note. The condemned artillery is almost exclusively composed of guns *worn out in service, and not obsolete until their lifetime is passed.* This cannot be said of the English, French or American rifles.

It is a fact not generally known, but which is of interest in tracing the history of rifled guns, that Russia tested and adopted the Krupp rifle before Prussia. That country was very decidedly in favor of breech-loaders from the start, and arrangements were entered into

with Krupp in 1862, so that as early as 1863 an $8\frac{1}{2}$-inch steel rifle was tested in Russia against $4\frac{1}{2}$ inch armor plates. From the results of these experiments, steps were at once taken to arm the forts and the fleets with this type of artillery. To Russia more than to any other country Krupp owes the rapid development of his factory. In 1866 he had built a $9\frac{1}{2}$-inch gun for this country and in 1867 an 11-inch. Immediately after settling upon the type of ordnance, the Russian government took steps toward establishing a home factory, and in 1863 a subsidy was granted to M. Obouchoff, who commenced work in 1864, and by 1867 his factory had advanced to the construction of $9\frac{1}{2}$-inch guns, all steel, which were fully equal to those made by Krupp himself. From that time to the present the Russian Krupp gun has held its own with those made at the mother factory.

In the United States, of all the types of rifled artillery that have been put forward as naval guns, the only one whose career merited the title of a development is the Parrott Rifle; and of all successful types ever developed, it is safe to say that none have been more maligned, with less reason than this. It first appeared about 1856 as a field piece, and was rapidly developed and improved until 1862, at which time it was the most powerful gun of its calibre and weight in existence. In that year the New Ironsides carried the first 8-inch caliber into action. The development of the gun ceased at this time; and its performance in 1865, when, in the attack on Fort Fisher, six guns exploded, killing 16 and wounding 23 men, condemned it. In 1874 the Parrott was converted into a breech-loader, being strengthened by the insertion of a steel tube on the Parsons plan, and an increased size of hoop. At the same time the 11-inch smoothbore was converted into an 8-inch rifle, and the line of type development of United States naval rifled artillery was marked out by the design of steel breech-loading 3-inch boat guns. In 1878 this first inception was expanded into a 6-inch steel rifle, and in 1882 the first designs of high-powered breech-loading steel artillery were determined and work was commenced on the construction of the guns.

The original Parrott rifle possessed several features of the highest merit at the time when it was adopted in the navy. It was strengthened by a coiled wrought-iron hoop, which afterward was the principal merit of the Woolwich type. Its rifling was polygrooved, with increasing twist, an adaptation universally used at present. It possessed for that time an extraordinary length of bore, which to-day is considered one of the most essential features of a high-powered gun. Finally, for its calibre and power it was the lightest gun in use.

The first error committed by the government with the Parrott rifle was, the total neglect to remedy apparent defects after it had been adopted. It came out of the war in 1865 as it had entered it in 1861, notwithstanding that its dangers and defects were well known, all of which could have been remedied easily even during the war. The second error was, in permitting the existence and growth throughout the service of the feeling of distrust for all rifled guns growing out of the accidents at Fort Fisher and elsewhere, and which would have been stopped but for the obstinacy of the support of the smoothbore in spite of the experience of the war and the well-grounded opinions of all Europe on the subject. The greatest error of all that was committed, was in commencing the new departure with the *conversion* of guns, and having commenced to convert, in the adoption of both the muzzle- and breech-loading systems. It is true that these guns were acknowledged to be "makeshifts" by the Navy Department, but a makeshift in any department of human labor is only permissible in case of the most extreme urgency. In 1874 the extreme urgency existed for the *possession* of rifled guns, but there was no urgency for their immediate *use*, therefore it was the *settled type* that was demanded and not the *makeshift*. The converted Parrott was a more powerful gun than the converted smoothbore, and if breech-loaders were to be the final type, then the expenditure on the conversion of smoothbores to muzzle-loading rifles was more waste than economy. If it was the intention to learn from conversion the manufacture of guns of an original type, then nothing was really gained, for nothing in the conversion except the breech-mechanism resembled the final type, and there was little, if anything, learned at the foundry which would be of use in original gun-building. Had the total conversion been confined to the Parrott rifle, the navy would to-day have at least had more rifled batteries than it possesses. Had original construction been undertaken instead of conversion, the development would have been far more advanced, and what is of the greatest importance, its effects would have been felt throughout the service now. By the careful method of a double system of conversion instead of a single method of construction, the navy broke no eggs, but in consequence it has no omelette. In both the navy and army it has been impossible to turn the eyes of the artillerists from the accumulations of pot-metal in the gun-parks. Years after French talent acknowledged itself fairly beaten in the attempt to utilize cast iron; when Great Britain and Germany have turned their backs upon

it; when no country, be it even half-civilized, will purchase a gun having cast iron in it; when the celebrated attempt of the Italian General Rosset, whose knowledge of cast iron for guns was second to that of no man living, and who brought to his work all the modern appliances, practical and theoretical, ended in an acknowledged failure; the United States government still hauls its old cast-iron guns from the parks, and goes over for the thousandth time the weary round of experiments. From this economic thraldom the navy has at length broken loose and development has actually commenced.

The first experiment made in England with rifled ordnance against armor was on October 8th, 1858. The gun used was a Whitworth cast-iron 68-pdr. muzzle-loader, which was quite the same pattern as the smoothbore of that name, except that its calibre was $5\frac{1}{2}$ inches. The target was a 4-inch plate backed by 7 inches of oak, and both cast and wrought-iron shot were fired at ranges of 350 and 400 yards with charges of 10 and 12 pounds of powder. The effect of the cast shot was not as great as that of the 68-pdr. round shot, but the wrought-iron projectile completely pierced the target. The crude condition of the rifle development in England at this date is exemplified in the difficulties encountered in this experiment. Seven shots in all were fired, of which the second missed the target altogether, the fourth jammed in loading and was wasted, and at the seventh shot the gun burst.

In the latter part of 1859 the Armstrong gun was first brought to bear against armor. This was an 80-pdr. muzzle-loader, used at a range of 400 yards with 10 pounds of powder, firing shells and both cast and homogeneous iron shot. Out of four *shells* fired at a 3-inch plate, two pierced it completely. Against a 4-inch plate, backed by 25 inches of oak, cast-iron shot only cracked the plate, homogeneous iron ones going clear through. Against a $4\frac{1}{2}$-inch plate and the same backing no shot could get clear through, although the plates were split and the backing torn. It was in the report on this experiment that the judgment was given that "vessels clothed in $4\frac{1}{2}$-inch rolled iron plates are invulnerable to existing artillery at all ranges."

In January, 1860, a Whitworth 80-pdr. was tried against a $4\frac{1}{2}$-inch plate with about 7 inches of backing, a conical-pointed projectile getting through. The gun was cracked at the third round.

In the early part of 1861 a special committee on iron was appointed, whose long and exhaustive experiments on iron armor for naval use have been ever since considered throughout the world as the standard of reference. The work done by this committee was remarkable,

and their judgments were exceptionally free from errors. There was but one naval officer attached to it, Captain Dalrymple Hay, the president of the committee. Fairbairn was one of the civilian members, and Noble, whose reports on ballistic experiments and the action of fired gunpowder have since given him a world-wide reputation as an expert, was under its orders. Dr. Percy, the foremost metallurgist of the world, was another member. The experiments carried on and the results obtained during the three years of the existence of this committee, placed England in the foremost rank of development both in armor and artillery. At the commencement of their work they divided into two separate branches, one of which took the firing ground as its base of operations and the other the laboratory, whilst Noble took charge of the branch of velocities of projectiles and pressures of powder. As a first step in their work they made a careful study of all the armor experiments that had been previously made, the most important of which have been described. They next called before them all the principal artillery experts and metal workers of England and ascertained their opinions upon all the details of the work which they were to undertake. Passing from these introductory steps, which familiarized all the members with the work in hand, they took up the work of the firing ground, and for three years submitted guns and armor to a most vigorous course of experiments. In their first report, made in March, 1862, at the end of their first year's work, appears a complete epitome of all the knowledge existing at that time with regard to the action of projectiles on armor. With regard to the work done and the methods used it states as follows:

"In order to ascertain generally what qualities were desirable in armor plates, as well as to determine the relative powers of resistance in plates of the same thickness but of different materials, we subjected to experiments plates of copper; of wrought-iron, hammered as well as rolled, and obtained from different manufacturers; of homogeneous metal; of steel; and of a combination of iron and steel. Several series of plates were prepared, each series consisting of plates $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ and 3 inches in thickness. In ordering these plates we took care not to restrict the makers to any particular make or quality of iron, merely explaining that the plates were intended to resist projectiles at high velocities, and leaving each maker to exercise his own judgment as to the most suitable quality for the purpose. In this way we secured as great a variety in the character of the iron as possible; so that, after experiment, we might form our own opinion

as to the special qualities to be desired in practice. The plates were all tested under the same circumstances. They were secured on wooden frames, without backing, and were fired at with projectiles varying in size and weight according to the thickness of the plates.

"Up to the present time we have not found any material so well adapted for armor plates as wrought iron of the softest quality. . . . The plates experimented on were manufactured by different processes. The Lowmoor plates were manufactured under both hammer and rolls. At the Thames Iron Works the plates were made from heterogeneous scrap and puddled bar, and were manufactured entirely under the hammer. In the plates of Beale & Co. pure scrap from their own works, in combination with puddled bar, was used, and the plates were manufactured by rolling. The Pontypool plates were made from charcoal iron and worked both by hammer and rolls.

"We have been led to the conclusion, that in order to produce the best armor plates it is by no means essential to employ the most costly description of iron. Charcoal iron and the highly esteemed varieties of Yorkshire irons possess no qualities which make them specially desirable for this purpose; and it seems certain that, with suitable care and sufficiently powerful machinery, good armor plates may be obtained either by hammering or rolling or by a combination of both, at a moderate cost.

"The experiments above mentioned served also for the investigation of the laws of resistance, in any given material, for plates of different thicknesses, to projectiles of different natures and weights and with different velocities. Mr. Fairbairn has been further guided by statical experiments on the same plates, carried on under his own superintendence.

"It appears that, up to a certain thickness of plate, the resistance to projectiles may be assumed to increase nearly as the square of the thickness. The measure of the absolute destructive power of the shot is not its *momentum*, as has been sometimes erroneously thought, but the *work* accumulated in it, which varies directly as the weight of the shot multiplied into the square of the velocity at impact. With all materials ordinarily employed as projectiles, a part of the work is lost through mechanical action on the shot itself (which either breaks up or becomes distorted), and through the rebound of the shot or its fragments after impact; but it is scarcely possible at present to ascertain the amount of work thus lost.

"As to the form of the projectile, Mr. Fairbairn has shown that in

statical punching experiments nearly twice the work is required to punch a plate with a round-ended as compared with a flat-ended punch. Both Mr. Pole and Mr. Fairbairn have given formulae expressing approximately the results of the experiments with ordnance. A combination of thin plates, instead of a single solid plate, had been recommended to the committee; but if it be true, as above stated, that the resistance of plates increases in a geometrical proportion to their thickness, it is clear that such a combination must offer far less resistance to shot than a solid plate of the same thickness. They were subjected to experiment and were found in every case far weaker than solid plates of similar thickness.

"We have found that plates are more liable to be damaged when struck near their edges, and we therefore recommend that they should be as large as possible, consistently with due economy in manufacture.

"On the subject of fastenings of armor plates we speak with hesitation; but it is certain that bolt-holes are not so injurious as has been supposed, and that if the bolts are in sufficient number and made of suitable iron, and of at least two inches in diameter, they form a tolerably secure means of attachment. The experiments show that the bolts have very important functions to perform. They have not only to hold the plate upon the side of the ship, but to resist the damage from vibration and to prevent the buckling of the plate in parts remote from the blow.

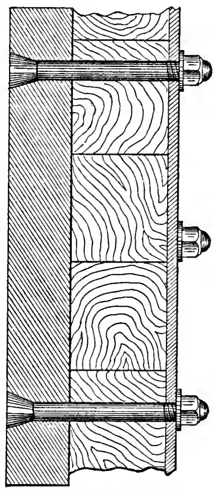
"All tonguing and grooving, or any departure from plane-edges, is a source of weakness to each particular plate; is liable to assist in destroying neighboring plates which would not otherwise be affected by a blow, and has structural disadvantages in preventing facility in repairing a damaged ship or changing a damaged plate. The result of experiment demonstrates that, however much the armor plates may be supported by direct contact with a rigid backing of iron, and however desirable it may seem to exclude wood or other perishable materials from them, yet the concussion is so injurious to the fastenings of a rigid structure that, in the present state of our knowledge, it would be unwise to recommend the abandonment of the wood backing."

The actual power of the English service rifle guns and the quality of resistance of armor plates, as determined by actual experiment at that time, appears from the following table:

Description of Gun.	Description of Shot.	Material of Shot.	Wt.	Diameter.	Charge of Powder.	Muzzle Energy	Penetration into Plates.
			lbs.	inch.	lbs.	ft. tons.	inch.
6-pdr. Armstrong	Cylindrical Flat-headed solid shot.	Cast-iron.	6¼	2.53	¾	59.2	1.00
12 " "	"	"	11½	3.02	1¾	107.3	1.53
25 " "	"	"	25	3.77	3⅓	235.3	1.50
40 " "	"	"	41	4.77	5	387.4	2.02
40 " "	"	Wrought-iron.	42	4.77	5	387.4	...
68 "Smoothbore	"	Cast-iron.	66¼	7.92	16	1146.4	1.5
100 " Armstrong	"	"	110	7.02	14	966.3	2.10
100 " "	"	"	200	7.02	10	690.0	...
120 " "	"	"	126	6.94	18	1207.4	1.70

Mr. Fairbairn found from his statical experiments on punching that the work done in causing fracture varied as the circumference of the punch, so that in future experiments, instead of taking into consideration the total striking energy of a projectile in comparing effects, the unit adopted was the striking energy per inch of shot's circumference.

In July, 1862, a very important experiment was made, with a disposition of armor designed for the water-line of the Minotaur. The object of the experiment was, to endeavor to ascertain whether the alteration from the Warrior plan (by doing away with 9 inches of the teak backing and adding in lieu thereof one inch to the thickness of the armor plate) was beneficial or otherwise. It will be remembered that in the Erebus and Meteor trial it had been proved that a thin backing was entirely unsuited for armor; afterward, the Fairbairn, Scott Russell and Samuda targets had proved that a rigid backing was unsuitable. The Minotaur target was an attempt to find out if a thickening of the plate could be accompanied by a reduction in the thickness of the backing. The target consisted of 5½ inch plates backed by 9 inches of teak, with the same skin and frame as was used with the Warrior. Each plate was fastened with three rows of bolts, the



Minotaur Target.

upper and lower being $1\frac{3}{4}$ inch and the centre $1\frac{1}{2}$ inch. The bolts in the immediate vicinity of the port-holes were iron wood-screws. The gun used in the experiment was a smoothbore, firing a 150 pound shot with 50 pounds of powder at a range of 200 yards. Four shots were fired. The first penetrated 13 inches, buckled the plate and started several bolts, cracked two ribs, broke four bolt-heads and eleven rivet-heads, and bulged the skin. The second shot made a hole clear through, 18 inches by 14 inches. The third shot was like the second, and the fourth, which was of wrought iron, remained in the target, but racked it more severely than any of the others. It was evident that the Minotaur target was very much inferior to the Warrior one; also that $1\frac{1}{2}$ and $1\frac{3}{4}$ inch bolts were too light. The report of the result also states that the progress in the manufacture of plates is not yet sufficient to guarantee regularity in the $5\frac{1}{2}$ inch plates.

Just previous to this a test had been carried on with Whitworth steel projectiles which proved that artillery development had overmatched $4\frac{1}{2}$ inch plates. These projectiles were made of homogeneous metal, a very mild or slightly carburized steel. The guns used for the trial were a 12 pdr. breech-loader, and a 70 pdr. and 130 pdr. muzzle-loader, rifled hexagonally on Whitworth's plan. At 200 yards range the 12 pdr. sent a solid shot through a $2\frac{1}{4}$ inch plate, the shot passing through unbroken and being set up only $\frac{1}{2}$ an inch. The same gun at the same range sent a shell through a 2 inch plate backed by 12 inches of oak, the shell bursting after getting through. No hollow projectile had hitherto passed through more than one inch of iron without breaking. The 70 pdr. was fired against a 4 inch plate backed by 9 inches of oak, having three feet in rear of it a 2 inch plate faced with 4 inches of oak, the whole being enclosed in a box. At 200 yards a shell was sent through the front target, and burst against the 2 inch plate, blowing the whole arrangement to pieces. The 130 pdr. was then tried against the Warrior target at ranges of 600 yards and 800 yards. Every shell fired pierced to the skin of the target, exploding at that point and blowing a hole clear through.

In the report made for the year 1862 the committee gave the following summary of conclusions arrived at:

1st. No material for armor-plates yet submitted to us has been found to be equal to wrought iron of the softest quality.

2d. All irregularities such as corrugations, projections, bosses, &c., are rather a source of weakness than of strength, it having been

proved that the best application of the material is a plain-surfaced plate of uniform thickness.

3d. Small and narrow plates are weaker than large and wide ones of the same thickness.

4th. Tonguing and grooving not only weakens each particular plate when struck by shot, but assists in damaging the adjoining plates.

5th. Combinations of bars are inferior to solid plates of the same thickness or weight of metal.

6th. A series of thin plates superimposed offers less resistance to projectiles than one solid plate of equal weight and area.

7th. In all trials which have been made with a view of testing combined substances in comparison with a solid iron plate of the same weight, the solid plate has been found in every instance to offer the greater resistance.

8th. No advantage is gained by opposing iron plates to rifled projectiles of good quality at an angle where, by doing so, the plate must be made thinner to compensate for a more extended area.

9th. The more rigid the backing the greater is the support to the plate; but, on the other hand, a soft backing has the advantages of yielding in some degree to the distortion of the plate, of distributing the effect of the blow over a larger area, of diminishing the damage to the general structure, and of retaining the broken fragments in case of fracture.

10th. For these reasons it is not desirable, as far as our experiments have yet shown, to construct any ships for war purposes without a wooden backing in rear of the armor plates.

11th. The reduction of the wood backing from 18 inches to 9 inches (as in the case of the Minotaur class of vessels) does not appear to be sufficiently compensated by an extra inch of iron; but the rapid improvement in the manufacture of thicker armor plates may obviate this difficulty.

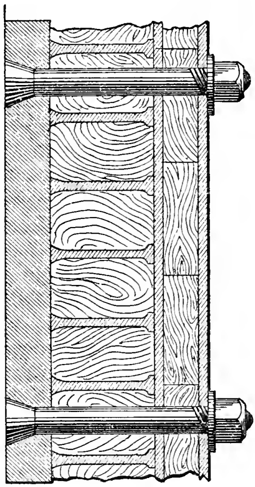
12th. No target yet experimented on by us has offered so good a resistance to shot as that which represented a portion of the midship section of the Warrior.

13th. A facing of wood or other soft substance upon armor plates affords a considerable amount of protection from solid shot, but is soon destroyed by shell.

14th. The best method of fastening which has as yet practically succeeded, appears to be the simple one of attaching the plates by

bolts of large diameter with countersunk conical heads and double nuts ; but it is desirable to relieve the jar by interposing a soft substance as a washer.

15th. The committee are of opinion that, successfully to attack armor-plated vessels, it is necessary that the shot should have a velocity on impact of at least 1000 feet per second.



Chalmer's Target.

In May, 1863, an experiment was carried on which, in the value of the results obtained, was one of the most important made by the Iron Committee—leading to an especial modification in the disposition of the backing of ships' armor plates. The target was the invention of Mr. Chalmers, and was composed of a $3\frac{3}{4}$ inch plate with a compound backing $10\frac{3}{4}$ inches thick, formed of horizontal layers of wood and iron plates; behind this was a second armor plate $1\frac{1}{4}$ inches thick, with a cushion of timber $3\frac{3}{4}$ inches thick between it and the $\frac{5}{8}$ inch plate forming the skin of the ship; the iron plates used in the backing were $\frac{3}{8}$ inch in thickness and 5 inches apart. The armor-plates were secured to the skin by through-bolts $2\frac{1}{4}$ inches in diameter, having stepped conical heads and a square thread, with double nuts and

elastic washers. The test given to this target was as nearly as possible exactly the one given to the Warrior target. There were 385 square feet in the face of the target, which received 7 shots from a 68 pdr. smoothbore, 18 shots from a 110 pdr. rifle, and 3 shots from a 150 pdr. smoothbore. Of these, 2 of the 150 pdr. shot pierced the target, and the general result proved it to be superior to the Warrior disposition.

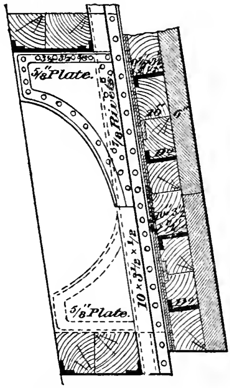
In the summarized report of this experiment the committee state as follows: "On the target being stripped, it was found that the $3\frac{3}{4}$ inch plates were much less distorted than the $4\frac{1}{2}$ inch plates on the Warrior target, and that the damage to the rear of the plates was much less than might have been expected from their thickness; the armor plates were forced back upon the edges of the filling plates by the blows of the projectiles, were furrowed by the contact in the immediate vicinity of the blow and indented to a considerable distance on each side, but were unbroken, and, except in one or two instances, uncracked.

"The backing proved much more substantial than the backing of wood without the interposition of the iron plates, which seemed to prevent the crushing of the wood and the spreading of the fracture to the contiguous portions of the backing. It would also probably tend to prevent ignition from the explosion of a shell, and evidently affords great support to the armor plates, as was shown by the furrows on the rear of the plates.

"It appears to the committee that the system of compound backing, adopted by Mr. Chalmers in his target, is of considerable advantage in adding strength and resisting power to the structure, and though it is more complicated and expensive than the ordinary wood backing, it may possibly be advantageously employed in certain portions of armor-plated vessels.

"This experiment has furnished additional confirmation of the advantages of bolts of large diameter, and also of the uncertainty of hammered plates."

The weights per superficial foot of the targets were, for the Warrior 341 lbs. and for the Chalmers 371 lbs. The results shown by the compound backing were immediately applied in an ironclad, which in general design marked almost a revolution in the line of development of English shipbuilding. The Bellerophon, the first of the ships turned out by Mr. Reed, after his appointment as Chief Constructor, was a sharp reform from the long, lean types of ironclads, commencing with the Warrior and ending with the Minotaur class.



Bellerophon Target.

In December, 1863, a target representing a section of her side between the main and lower decks was tested, and this target is an important one, as representing a step in the development of armor for ships' sides. The skin was composed of two thicknesses of ¾-inch plating, riveted together, with a layer of painted canvas between. On the outside of the skin-plating were riveted horizontal angle-iron stringers 9½x3½x½-inch, the broad flange being square to the skin, every other one reaching out to the armor-plates. Wood backing 10 inches thick was worked longitudinally on the skin-plating and between the stringers, bolted to the skin with through-bolts. The armor-plates were 6 inches thick, secured by 2½-inch bolts. In this target the supports were counterparts of the beams and knees of the ship herself. The target differed from the Warrior in the following points:

1st. The adoption of the Minotaur principle of increasing the thickness of armor-plate and diminishing that of the backing.

2d. The adoption of the Chalmers principle of interlaying horizontal plates; the modifications being that they were converted into longitudinal stringers by riveting to the skin, thus adding to the strength of the hull, and by leaving the outer edges ½ inch short of the armor-plates, giving a cushion and relieving the impact strain on the skin.

3d. A large increase in diameter of bolt fastenings.

4th. An increase in thickness of skin of almost double.

The weight of the target per superficial foot was 400 lbs. or about 17 per cent. more than the Warrior's. The total area of the target was 393 square feet, and against it were fired, at a range of 200 yards, three 10½-inch spherical shot, two 7-inch Whitworth steel shells, one 5½-inch Whitworth steel shell, four 110-pdr. Armstrong shot and three 68-pdr. shot.

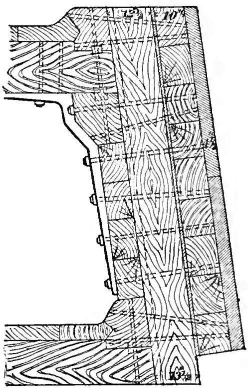
The target was not pierced; not a single bolt provided with elastic washers was broken, although several were squarely hit; the target was considered perfectly successful, and the resistance of the armor-plates showed that, whilst plates of 6 inches thickness were still of a variable nature, the development of certainty in the plate manufacture had passed the 5½-inch limit.

In November, 1863, the committee reported the results of the first trial with the Palliser chilled projectile; the report being as follows:

"The chilled 12-pdr. shot which were manufactured in the Royal Laboratory on the plan proposed by Captain Palliser, all broke up on impact, but they showed a marked improvement on the common cast-iron shot of the service, the indent of which on the 2½-inch plate is 0.75 inch, whilst an average of four shots of chilled cast-iron gives an indent of 2 inches, and in two instances the 2½-inch plate was broken through." Extensive experiments were carried on with steel and homogeneous iron projectiles during the year, and the committee reported very strongly the necessity of adopting some type of steel armor-piercing shot.

Shortly after the test of the Bellerophon target, another disposition was arranged for the wooden-hulled ironclads, Lord Warden and Lord Clyde. The side target as originally designed, consisted of the inner planking 8 inches thick, frame-timbers (filled in solid) 12½ inches, outside planking 10 inches, and armor-plates 4½ inches; the complete target being about the same in strength as that of the Gloire. During the construction of the Lord Warden it was found that the hull could be lightened sufficiently to permit of the addition of armor equivalent to a thickness of 1½ inch all around. The question whether this thickness should be put into the armor-plate itself, applied as a separate plate to the rear of the plate, or between the frame and outside planking, was thoroughly discussed, and Mr. Reed determined to place it between planking and frame. There was much fault found with this decision, as, owing to the very excellent

results obtained from the Chalmers target and the strong recommendation of the Iron Committee to the Admiralty, it was considered that a much stronger target could be made by utilizing the extra weight in a Chalmers disposition. The result of the firing test proved the validity of the objections, for the Lord Warden target broke down completely, being easily pierced by the 9 and 10-inch rifles firing spherical steel projectiles.



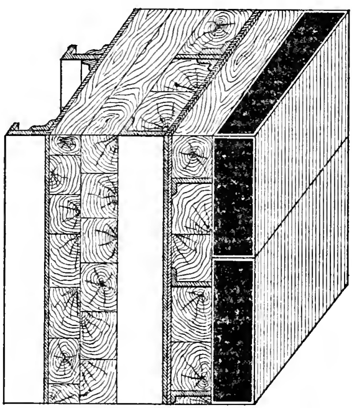
Lord Warden Target.

A few months after this test an experiment was made with a target representing the Gloire and Flandre sections; French plates being used. The Flandre and the Lord Warden sections compared very closely in structure in all except the single additional plate of the latter between the frame and outside planking, thus:

	Flandre.	Lord Warden.
Inner planking	6 inches.	8 inches.
Frame-timbers	11 "	12½ "
Outer planking	10 "	10 "
Total wood	27 "	30½ "
Armor plate	6 "	4½ } 6 in.
Additional plate	...	1½ }
	33 "	36½ "

The plates of the French target were small as compared with those usually applied to English ironclads, being about 7 feet long by 3 feet wide. The target gave practically the same result as regarded resistance as the Lord Warden's, the general summary of the test stating that it could be pierced by the 9-inch gun up to 1400 yards, whilst it successfully resisted the 68-pdr. smoothbore and 7-inch rifle.

For a short time the Warrior target had been declared invulnerable to existing ordnance, but the advent of the 15-inch smoothbore in the United States and the 7-inch Whitworth rifle in England had robbed it of its preëminence. The Minotaur disposition was practically a failure; the Gloire and then the Flandre types fell to the rear; the Lord Warden type was a step backward, and the Bellerophon, although, thanks to Chalmers and his system of supporting backing, a long step in advance, was still behind the artillery in development. In 1865, however, for the second time, armor caught up with artillery in the disposition made for the water-line of the Hercules.



Hercules Target.

The construction of her target was as follows: The upper half was faced with 9-inch plates and the lower half with 8-inch; behind both plates were 12 inches of horizontal timber, with Chalmers strengthening plates, whose outer edges touched the back of the armor. These stringers were riveted to two ¾-inch skin plates, the whole being secured to the hull frames, which were 10 inches deep, filled in

between with vertical timber. Behind these filled frames again were two linings of horizontal timber, 18 inches deep, not bolted, but confined by 7-inch iron ribs inside all. (This inner lining occupied the space devoted to wing-passages in the earlier ships.) The bolts were 3 inch, half of them being of the Palliser type. The plates were manufactured by Cammel & Co., and the weight of the target per square foot was 689 pounds for the thicker section and 652 pounds for the other, or about double that of the Warrior.

Against this target were brought to bear a 9-inch shunt rifle at a range of 200 yards, whose striking energy was about 3200 foot-tons; a 10-inch shunt rifle at 200 yards, with a striking energy of about 3800 foot-tons; a 10½-inch shunt rifle at 200 yards, with a striking energy of about 3400 foot-tons, and a 13-inch shunt rifle at 700 yards, with a striking energy of about 6870 foot-tons. Thirteen shots in all were fired, of which six were from the 13-inch.

The greatest effect was produced by two shots (a 9-inch and a 10-inch), which struck close together on an 8-inch plate; the damage being limited to the penetration of the plate and about 9 inches of the backing, the two ¾-inch plates being slightly bulged. In no instance was the armor penetrated when struck on a sound place, although the committee reported that the plates were not of first-class quality. The opinion of the committee on the results of the experiments was as follows:

"1st. That a structure such as is represented by the Hercules target appears to be practically impenetrable by the heaviest known ordnance so long as it is in a sound state; and it appears to them to be a question well worth the consideration of the Lords of the Admiralty whether it may not be advisable to reduce the power of defense in the Hercules by substituting 8-inch iron plates for the 9-inch now proposed, and increasing her power of offence by adding the weight which would thus be economized to that of her proposed armament.

"2d. That steel shells of the Armstrong form are valueless as shells when fired against such a structure.

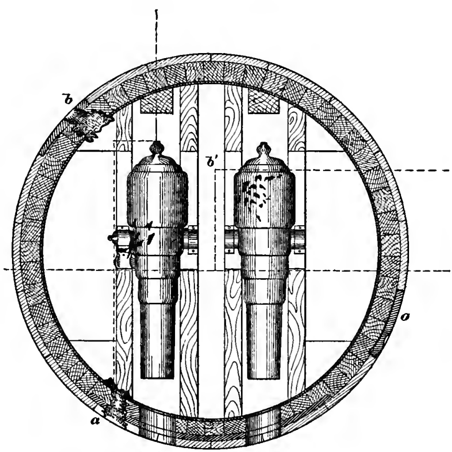
"3d. That chilled iron at £20 per ton appears to be as good a material for armor-piercing shot as steel at £80 per ton, at least in the form of projectiles used in this experiment.

"That the employment of armor-plate bolts of large sectional area has proved entirely successful. Of the two descriptions under trial, viz. those of ordinary form and those of Major Palliser's design, the latter have maintained their superiority."

This excellent result gave to the Hercules a great reputation as an invulnerable ship. She was completed in 1868, and in August, 1869, the Russians practiced with one of their new 11-inch rifles against a Hercules target, identical in every respect with her midship section at the water-line, *and pierced it without difficulty at 1200 yards.*

In February, 1868, during the war between Brazil and Paraguay, the Brazilian monitor Alagoas was put to a very severe test, which is of great interest, as her side armor corresponded closely in resisting power to that of the Passaic class of United States monitors.

The side armor of this vessel was made up of 4½-inch solid plates backed with 15 inches of teak and a ½-inch skin. Her turret carried 6-inch solid plates backed by about 10-inch teak and two ½-inch skin plates. In an attack on some Paraguayan batteries she was struck 200 times, her side armor being pierced twelve times and her turret twice. The armament of the batteries consisted of Whitworth 32-pdr. rifles, 68-pdr. and 120-pdr. smoothbores, and the range for the greater part of the time was less than 100 yards. The turret was very badly damaged; nearly all the bolts being broken, and the wood-backing being badly crushed in several places.



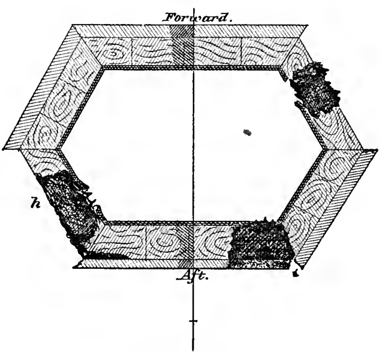
Huascar's Turret

The fight between the Huascar, Cochrane, and Blanco Encalada, although occurring in 1879, belongs to the period of development of both armor and guns marked by the close of the year 1868. The side armor of the Huascar consisted of $4\frac{1}{2}$-inch solid plates, tapering at the bow and stern to two inches, backed by ten inches of teak with a $\frac{5}{8}$-inch skin plate. The turret had $5\frac{1}{2}$-inch solid plates backed by 13-inch teak, with $\frac{1}{2}$-inch skin plate. The section of the turret in front of the guns was reinforced by a 2-inch plate, the backing being correspondingly reduced. The conning tower consisted of 3-inch plates backed by 8 inches of teak, with two $\frac{1}{2}$-inch skin plates forming the inner shell or foundation. Against this armor, 9-inch Armstrong muzzle-loaders were brought to bear, at ranges varying from 2000 yards to close aboard, and with the following results:

(*a*) Pierced the turret armor through the plate forming the right half of the right gun-port, the angle of impact being about 30° from the normal. Projectile exploded in the backing. The hole through the plate was about 9 inches in diameter and quite round. The left edge of the plate was driven back two inches, the upper right edge being driven out one inch. One bolt started out about one inch.

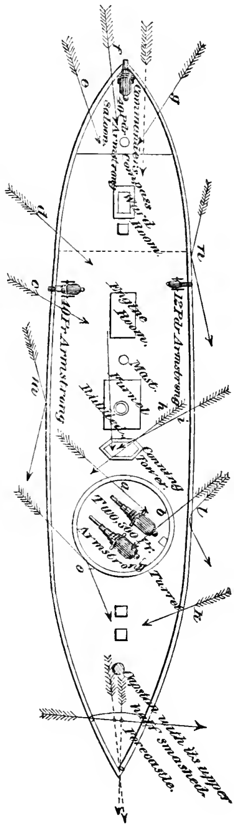
(*b*) Pierced the turret armor near the right side of the breech of the right gun, making a hole 15 by 12 inches. The plate was driven back on one side $1\frac{3}{4}$ inches and was split into three layers, showing poor welding. The ring around the top of the turret was broken and bent up. No bolts were broken. Shot burst in the backing.

(*o*) A glancing shot on the turret making a score 10 inches long by 2 deep, setting the plate back one inch. One other shot glanced on the turret, doing no harm.



Huascar's Conning Tower.

(*h*) Pierced one of the after corner plates of the conning tower and burst in the backing of the opposite side, forcing off the plate, which fell on deck.



Plan of the Huascar (Showing hits by shot).

(*i*) Pierced the after plate of the conning tower, exploding in the inner space.

(*c*) Pierced a side armor plate abreast the engines and burst in the backing, tearing a hole 48 by 38 inches.

(*e*) Pierced a plate on the starboard quarter and burst in the backing, making a hole 48 by 36 inches; broke two deck beams and started the spar-deck up. Broke the tiller chains.

(*f*) Pierced the armor near the stern-post, exploded in the backing, breaking off the head of the stern-post, breaking three deck-beams and carrying away the relieving tackle.

(*g*) Pierced the armor on the port-quarter and burst in the backing, tearing an irregular hole.

(*l*) Glancing shot on the upper edge of the armor abreast of the turret, scoring the side armor.

(*k*) Pierced the armor forward of the turret-chamber, bursting in the backing.

(*m*) Glancing shot abreast the smokestack. Indented the armor, but did not crack it.

(*n*) Glancing shot abreast the main rigging, making an indentation two inches deep.

This action was remarkable for the proportion of effective shots on the Huascar's armor. Out of four shots on the turret two were effective. Three on the conning tower, all effective. Eight on the side armor, five of which were effective. Although the other ships were hit several times by the projectiles of the Huascar's 10-inch shunt guns, no damage was done.

The demands for increased thickness of plates were a source of more than annoyance to armor manufacturers, for they required a continued remodelling and increase of power of armor plant; and even with the most perfect appliances available it was impossible to produce plates of more than six or seven inches in thickness that could be depended upon for quality. Experiments were, therefore, carried on in England in 1867, with a disposition called the "plate-upon-plate" system, in which thick plates were applied in direct contact in several thicknesses. This disposition, although the same in principle as the "laminated" one, was distinct from it in using thick instead of thin plates. The first series of experiments was carried on with targets manufactured by Cammel & Co. One target was a single 7-inch plate; a second was made up of two 3½-inch plates bolted together, and a third consisted of three 2⅓-inch plates, riveted and bolted. Against these targets a 7-inch gun was used with Palliser chilled projectiles. As a result it was found that the solid plate required per inch of shot circumference an energy of 56.6 foot-tons; the double plate required 54.9, and the treble plate 50.8 for complete penetration; or, calling the solid plate the standard, with the figure of merit of 100, the double plate would be represented by 96 and the treble plate by 89. Much fault was found with this experiment, and a few months afterward another test was made on thicker plates, using a single plate target of 10 inches and a double plate of 5 inches. It was found that the resistance of two 5-inch plates was exactly three times that of a single 5-inch one, which according to the theory of the resistance increasing as the square of the thickness, which had been proved true up to 4 inches, would make the double plate 28 per cent. less in power than a single 10-inch one. As a matter of fact, however, the first 10-inch plate tested broke down completely at the first shot, and upon a repetition of the trial the *empirical* laws were deduced, that two plates bolted together were barely pierced by the 9-inch projectile; two plates slightly separated were not completely perforated; and a single plate was readily pierced and to spare. These laws only applied as long as plate manufacture was in its imperfect state, and were only true of the plate-upon-plate disposition. A third series of experiments was carried on in 1868, whose results were often quoted in the United States as proving the "laminated" disposition to be the best. In this experiment a single 15-inch plate was tested against three thicknesses of 5-inch plates and a target of fifteen 1-inch plates. In this,

the solid plates broke down under the first shot, and the laminated target resisted somewhat better than the plate-upon-plate one.

Ever since the introduction of the Woolwich rifle, a strong rivalry had existed between it and the Krupp breech-loader in development. The English had apparently kept the lead, and in 1868 it was decided by the Prussian government to purchase an Armstrong 9-inch gun, with its English powder and projectiles, and test it against armor-plates in direct competition with their newly designed 24-centimeter (9½-inch) gun. Three targets were provided for this purpose. No. 1, consisting of a 6-inch plate with 10-inch teak backing and a 1-inch skin. No. 2, a 7-inch plate with 30 inches backing; and No. 3, representing a section of the Konig Wilhelm, an 8-inch plate with 10-inch backing and ¾-inch skin. The guns were put in position at a range of 950 yards from No. 1; 750 yards from No. 2, and 500 yards from No. 3. The following were the charges and energies of the two guns:

	Krupp.	Armstrong.
Diameter of projectile	9.27 inches.	9.0 inches.
Weight " "	335 lbs.	250 lbs.
" " charge	49½ "	43 "
Initial velocity	1141 feet.	1313 feet.
Muzzle energy, per inch of circumference	108 foot-tons.	109 foot-tons.

Four shots were fired from the Armstrong at No. 1, two at No. 2 and one at No. 3. The Krupp gun fired but two shots; one each at No. 1 and No. 3. Every shot from the Armstrong pierced its target. The first shot from the Krupp at No. 3 pierced the 8-inch plate and 7½ inches of the backing. The second pierced No. 1 target, the projectile breaking up after passing through. The Armstrong gun showed a decided superiority, and as a result Prussian artillerists were for a time about equally divided in opinion as to whether it was good policy to carry on the development of the breech-loader or to adopt the Armstrong muzzle-loading system. Orders were given for another trial, and the advice of Krupp was taken with regard to certain modifications in the breech-mechanism and powder-charge. In July, 1868, a second test took place against the Konig Wilhelm target, which showed a marked improvement in the power of the Prussian gun, which this time gave a greater penetration than the Armstrong. In August a third test was given, and this time the Prussian gun showed a decided superiority; to such an extent was

this the case that a 21-centimeter gun (8¼-inch) was pitted against the English 9-inch, and gave greater penetration at medium ranges; much of this effect was due to the better quality of the projectiles of Gruson chilled iron and Krupp steel.

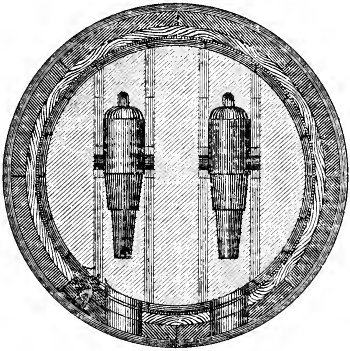
As a final test of the power and endurance of the two descriptions of guns, orders were given to fire 600 rounds from each gun (24-centimeters and 9-inch) with full charges and projectiles. At the 138th fire of the Woolwich gun, the inner end of the vent began to give way, a crack commencing to show, which at the 291st shot had extended 24 inches, and at the 299th shot was 30 inches long, opening out so as to give certain evidence that the steel tube was cracked through. The gun was at this point considered to have reached the end of its life and the test was not carried farther. The Krupp gun fired 676 shots. After the 430th round the vent began to show signs of giving out. At the 660th shot a Gruson shell exploded in the gun and started a crack, which increased in length rapidly until the gun was decided to be untrustworthy. During the whole firing the breech-mechanism had not given out or showed signs of failure. This test decided the Prussian government finally, and the 21 and 24-centimeter guns were formally adopted as naval guns.

During the same year that these experiments were carried on in Prussia, corresponding ones were made in Russia and Belgium, to test the power of the 9-inch gun against armor. In both of these countries guns of exactly 9-inch calibre were chosen, although they were of the Krupp type. The target used at St. Petersburg consisted of an 8¼-inch plate backed with 32 inches of oak; complete penetration being obtained at a range of 225 yards. In Belgium, two targets were used, representing the Bellerophon and Warrior water-lines. Both targets were pierced at 250 yards.

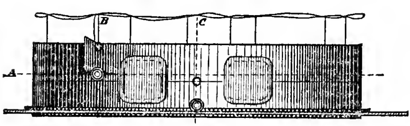
From these experiments it is seen, that in 1868, when the 9-inch rifle may be said to have established itself as a fully developed calibre, armor was still behindhand in resisting power. The factories were hardly able to turn out 9-inch plates whose excellence could be guaranteed, and the water-line belts of the ironclads belonging to this period (the Monarch and Invincible in England, Ocean and Marengo in France, Venezia and Roma in Italy), were easily penetrable at ordinary fighting ranges by the guns which they carried in battery.

In 1872 an experiment was made in England, with the turret of the Glatton, which ranks next in importance to the fight of the

Huascar in the results obtained. The turret-plates of the Glatton were 12 inches thick (two tiers high), except the two port-plates which were 14 inches; backed by 15 inches of oak behind the port-plates and 17 inches elsewhere; with two ¾-inch skin-plates, making in all a solid thickness of wall of 30½ inches. To the skin-plates were riveted vertical angles, 5 inches in depth, to which again was attached a ½-inch mantelet to catch splinters. The Glatton was moored in position with her turret in order for action, guns in place

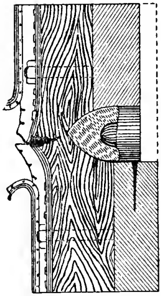


Section at A.

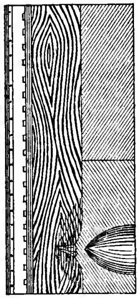


Elevation.
Glatton Turret.

and revolving gear ready for work. A number of fowls and animals were put in the turret in order to test the effects of heavy blows on the brain. Three shots were then fired from the 12-inch rifles of the Hotspur, at a range of 200 yards, with 600 lbs. projectiles and 85 lbs. charges. The first shot barely grazed the top of the turret and was thrown out of account. The second one struck one of the upper tiers of 14-inch port-plates at its lower edge, with the following effects. Total penetration 20½ inches. Upper plate forced back at lower edge 5½ inches. Horizontal joint between the



Section at D.
2nd. Shot, Glatton Turret.

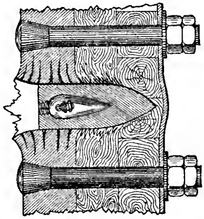


Section at C.
3rd. Shot, Glatton Turret.

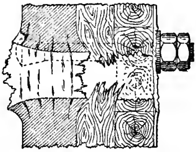
upper and lower plates opened out 2 inches. Lower plate showed a lamination split. One bolt driven partially in, the nut flying off into the turret. The double skin bent back and forced open to a width of about 3 inches, through which the wood backing protruded. Mantelet torn open, leaving a gap 48x18 inches, so that a number of rivets and bolt-nuts were driven through into the turret.

The third shot struck the glacis-plate and glanced up on to the lower 14-inch turret-plate, penetrating 15½ inches. Glacis-plate deeply grooved and cracked. Flange-ring covering the joint of turret and glacis cut through and bent. No interior damage. After this shot the turret was revolved, and four shots were fired from its two 12-inch guns with full charges. Both the turret and the guns worked with perfect freedom and none of the animals or fowls were at all injured.

Two months after the Glatton experiment an armor test was given in Prussia to the new 28 and 26-centimetre (11¼ and 10¼-inch) Krupp rifles. The target consisted of a 12-inch plate backed by 18 inches



12 inch Plate,-10 inch Krupp Gun.



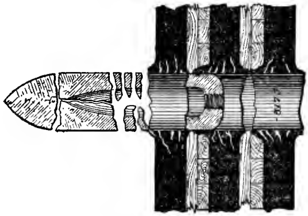
12 in. Plate-11 in. Krupp Gun.

of oak, with a ⅝-inch skin, the range with both guns being 175 yards. The powder charge for the 10¼-inch gun was 73 pounds, being but two pounds less than that used by the 12-inch in the Glatton test. The charge of the 11¼-inch gun was 88 pounds. The greater length of these guns made possible a complete combustion of the heavy charges, so that these guns rated in power with Woolwich artillery of about one inch greater calibre. In this respect the wisdom of the line of development followed in Prussia is well shown by the results. Whilst in England it had become a matter of calibre alone in increasing the power, in Prussia every branch of the subject was carried along at once, so that whilst their guns were smaller than the Woolwich, they were fully equal to the best in power.

The 11¼-inch Gurson projectile pierced the target, breaking up into five large pieces. The head of the shot remained sticking in the backing, all the rest being blown out backward by the explosion of the shell charge. The 10¼-inch pierced the plate, but was held in the backing. A second shot fired with the same charge against a 10-inch plate, backed by 18 inches oak and a ⅝-inch skin, pierced the target clean, breaking up in the rear. A 21-centimeter gun (8¼-inch) fired at a 9-inch plate with the same backing barely pierced the target, so that it was considered as a fair measure of the highest power of that gun. These experiments show the development of artillery with which armor had to contend in a remarkable manner. In all cases the backing and skin were practically the same as those used with the original Warrior targets. The difference in power of resistance was measured by increased thickness of plate. In 1863 it had been declared that the 4½-inch plate over such a backing made a ship invulnerable. In 1868 it required a plate of double the thickness, and in 1873 three times the thickness to keep out projectiles. In 1863 the 300-pound spherical projectile could not pierce the Warrior target at 500 yards. In 1873 the 6-inch rifled projectile would pierce it clean at the same range.

In passing from 4½ to 6-inch plates the great increase in weight of armor had necessitated a marked reduction in the space covered on the sides of ships. At first the armor was stripped from all parts except the water-line and battery. Soon it was necessary to, in a manner, sacrifice thickness on the battery in order to cover the water-line. With the introduction of 12-inch plates the limit of guaranteed regularity of manufacture seemed to be reached, and the great cost of production, difficulty of fabrication, especially with plates of double

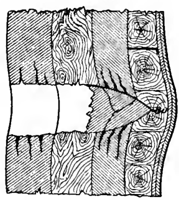
or even single curvature, and the reduction in area of single plates consequent upon increased thickness, forced the armor designers to seek a new departure. At first it seemed as if the plate-upon-plate method would satisfy the demands, but it was soon found to be impracticable in actual application on account of the difficulty of making the plates fit each other exactly. Flat plates had to be planed to true surfaces, almost doubling the price of manufacture, and it was found absolutely impossible to fit curved plates snugly.



Sandwich Target.—12½ inch Woolwich Gun.

In consequence of this difficulty the method of "sandwich" armor was introduced, differing from the plate-upon-plate system in the point of the insertion of a certain thickness of backing between the layers of plates. The thickness of this backing was limited by the size of projectile that would just pierce the plate outside of it; that is, if the outer plate was 7 inches in thickness and required an 8-inch projectile to pierce it, it was thought that the sandwich backing should be about 8 inches thick. This arrangement was made on the theory that a shell should not be allowed to pierce a plate and exert the power of its explosion on the backing so as to drive the plate out. The first application of the sandwich system was made in the turret of the Dreadnought, which was made up of an outer 7-inch plate backed by 9 inches of teak, then a second 7-inch plate backed with 6 inches of teak, and a skin made up of two ¾-inch plates. The total solid thickness was thus 30½ inches, almost evenly divided between iron and wood, the thicknesses closely corresponding with those of the Glatton. The absolute resisting power of the target was superior to that of the Glatton in the more perfect manufacture of the individual plates. Whilst, however, the turret was strong enough to keep out the service 12-inch projectile, it was not equal to the power of the guns composing the armament. Woolwich development had passed to the 12½-

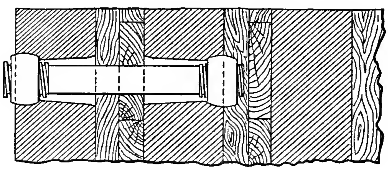
inch calibre, which gained much in power by having an enlarged chamber, an increased length of bore, and gas-checks on the projectile to seal the windage-ring. This gun as first manufactured had the normal chamber, carrying a charge of powder of 130 pounds, with an 812 lbs. projectile. In this condition it was tried against a sandwich target, made up of three 6½-inch plates, with 5-inch teak layers between; the range being 70 yards. The shot pierced the target, breaking up in passing through and leaving the base sticking in the last plate. This target was afterwards strengthened by bolting to its face a third layer of 5 inches of teak and a fourth 6½-inch plate, making a total thickness of 26 inches of iron and 15 inches of teak. The chamber of the gun being increased to hold a charge of 200 pounds, a shot was fired at the reinforced target with the same weight of projectile as before and at the same range. The total penetration was 36½ inches, of which 21½ was through iron. Even this remarkable result was not considered to have shown the full power of the gun, as the loading was not satisfactory.


Sandwich Target,-12 in Krupp Gun

During the same year a 12-inch Krupp gun was tested in Prussia against a sandwich target, giving a still higher comparative result. The target consisted of a 10-inch face-plate with 8 inches of oak, a 6-inch plate, 8-inch backing, strengthened by iron stringers and a skin of two 1-inch plates. The range was 225 yards, charge 132 lbs., projectile 670 lbs. Both plates were pierced, and the point of the shot entered the rear backing 7½ inches, bending the skin-plating back 3 inches.

The year 1876 marks the introduction of the mammoth rifle guns, as on September 17th the 81-ton Woolwich gun commenced its firing test at Shoeburyness. The year before that Krupp had completed his first 35½-centimeter (14¼-inch) gun, and shortly after the completion of the 81-ton gun, Krupp responded with a 40-centimeter

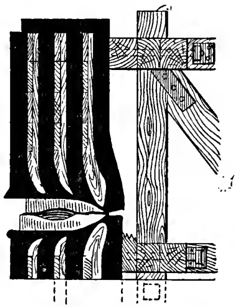
(16-inch), whilst Armstrong had completed the first 100-ton (17-inch) gun in June, 1876. It had been the intention to give the 81-ton gun a finished calibre of 15¾ inches, but with this diameter of bore the disparity in power when compared with the Krupp 35½-centimeter sent it back to the workshop after the first firing to raise the calibre to 16 inches, which the extra strength of the construction permitted. The Krupp 14¼-inch weighed but ⅗ of the amount of the 81-ton gun, whilst the muzzle-energy of its projectile was 2½ per cent. greater. More than this, whilst the 81-ton gun was built for the armament of the Inflexible, the Krupp 35½-centimeter would pierce that ship's armor at 2000 yards range. Although with its increased calibre, the 81-ton surpassed the 35½-centimeter, it was left behind by the 40-centimeter; the latter gun was forced to the second place by the Armstrong 100-ton, and this gun was beaten by Krupp again in the new model, 30½-centimeter (12-inch) gun, which has a length of bore of 35 calibres, and weighs 49 tons or scarcely half as much as the big Armstrong.



Fastening of Sandwich Plates.

The first armor test given to the 81-ton gun was against a sandwich target designed by Col. English, consisting of four 8-inch plates with 5-inch layers of teak between. The bolts of this target were of an improved Palliser type, the screw-thread being above the line of the shank, whilst spherical heads were screwed on each end, and the metal of the plate was kept clear of the shank, thus allowing a limited play to the plates to prevent shearing. Alternate plates were tied together by these bolts, there being no through bolting. Two shots were fired against this target with 1700 lbs. projectiles and at a range of 120 yards. With the first shot the charge was 370 lbs. and with the second 425 lbs. In the first case the point of the projectile actually penetrated about 25 inches of iron, or a total penetration of 55 inches; projectile broke up and the head securely plugged the shot-hole. In the second shot the projectile pierced 26 inches of iron

and 15 of teak; but the total penetration measured from the face of the target was 7½ inches greater than in the first case, the difference being caused by the greater bulge in the back of the target. The point of the shot was visible from the back of the target through cracks opened nearly 3 inches.

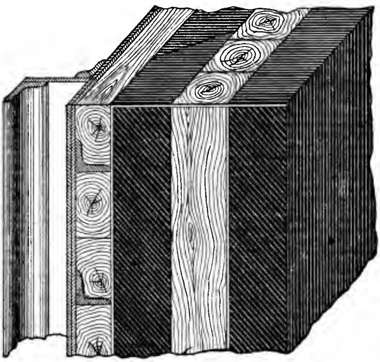


Sandwich Target,- 81 Ton Gun.

A good idea of the superiority of the Prussian method of artillery development over the Woolwich one is furnished by comparing these effects with the result of a shot fired in 1879 at Meppen. The target in this case was a sandwich, made up of a 12-inch front-plate and 8-inch rear one, with 2-inch oak between. Against this, at a range of 170 yards, a 9½-inch Krupp gun was fired with a charge of 165 lbs. and a Krupp steel projectile 348 lbs. The target was pierced and the shot took ground 3937 feet beyond the rear face. It was shortened three-quarters of an inch but was otherwise uninjured. If this shot be compared with the Glatton experiments, it will be at once seen that the Krupp 9½-inch weighing just about half as much (17¾ tons) as the Woolwich 12-inch, is far superior to it in power.

In designing the Inflexible it had been the intention of the English Admiralty to secure an ironclad that should far surpass all others, both in power of artillery and strength of armor. In order to get the necessary armor strength it was considered inadvisable to attempt the construction of solid plates, and as the sandwich arrangement applied to the Dreadnought presented a strong and economical disposition, it was introduced in the design of the Inflexible's armor, which

consists of a 12-inch plate, 11-inch teak, a second 12-inch plate, 6-inch teak strengthened by angle-iron girders, and a skin of two 1-inch plates. The outer 12-inch plates keep the same thickness throughout the height of the redoubt, but the inner one is confined to the water-line strake, the others being but 8 inches in thickness (penetrable, therefore, by the Krupp $9\frac{1}{2}$-inch gun).

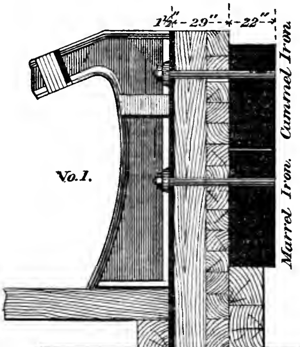


Inflexible's Armor.

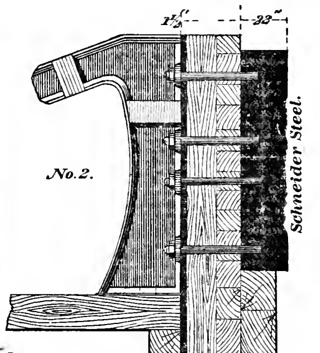
This decision with regard to the Inflexible's armor is a most interesting feature in armor development. Simultaneously with the design of the ship, the Italians, possessed with the craze for building the most formidable vessel afloat, prepared the designs of the Duilio and Dandolo, whose displacement tonnages were about 1000 tons less than the Inflexible. In both the English and the Italian ships the new idea of placing the turrets in echelon was first introduced, and to which nation belongs the credit of the original inception never has been satisfactorily determined. Whilst the Italians had the smaller ships, they determined to outdo the English in both offensive and defensive power, so that almost simultaneously with the design of the Inflexible's 81-ton guns at Woolwich, Armstrong received orders for the design of 100-ton guns for the Duilio. No sooner had the Admiralty determined upon the disposition of armor for the Inflexible than the Italians called for test-plates of 22-inch solid armor from all the prominent manufacturers in the world. The four best makers in Europe entered at once into competition, the rivalry being so much

the stronger since two of the firms were English and two French. As a result, in the autumn of 1876 the famous Spezia experiments took place which completely revolutionized armor manufacture in Europe.

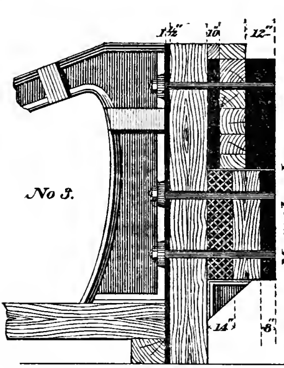
Of the four firms entering into competition, Cammel & Co. submitted one solid and one sandwich iron target; Brown & Co. submitted two solid iron targets; Marrel et Cie. one solid and one sandwich iron target, and Schneider et Cie. two solid *steel* targets.



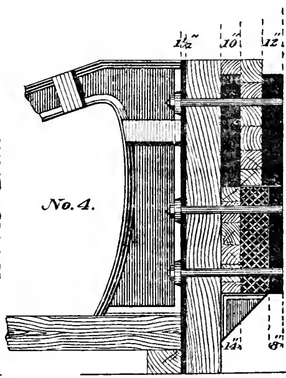
Upper Target Cammel Wt Iron 22" thick.
Lower Target Marrel Wt Iron 22" thick.



Schneider Target.
Creusot Steel plates 22" thick.



Upper Target Marrel Wt Iron, (Sandwich plates) Lower Target Wt Iron & Chilled Iron (Sandwich).



Upper Target Cammel Wt Iron, (Sandwich plates) Lower Target Wt Iron & Chilled Iron

Four main structures or targets were built, made up as follows: No. 1 held two 22-inch iron face-plates, 12 feet long by 4¾ feet wide, the upper one being a Cammel and the lower one a Marrel. These plates were backed by 29 inches of teak, with a 1½-inch skin, the whole being supported in rear by heavy girders and beams. The plates were secured by 4-inch through-bolts, with countersunk heads, and nuts over rubber washers in rear.

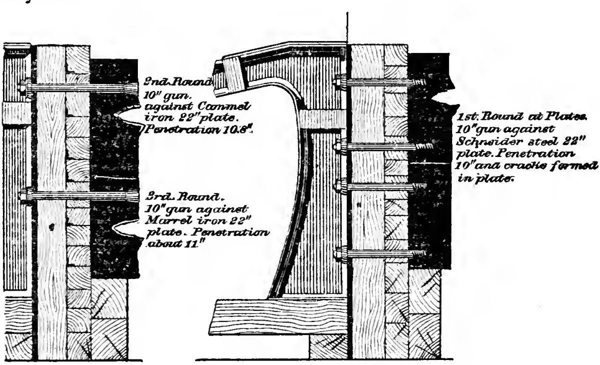
No. 2 held two 22-inch steel face-plates, both of Schneider metal, of the same dimensions and with the same backing as No. 1. The fastenings were, however, a new departure in bolting, the bolts being screwed into the plates from the rear about half-way through the plate, and then the whole was set up with the nut and rubber washer. Schneider also used double the number of bolts applied by the others.

No. 3 was a sandwich target, in two divisions, the upper part consisting of a 12-inch iron Marrel face-plate, 12-inch backing, 10-inch plate, 16-inch backing and 1½-inch skin. The lower half was an 8-inch iron Marrell face-plate, 12-inch backing, 14-inch chilled cast-iron Gregorini plate, 16-inch backing and 1½-inch skin.

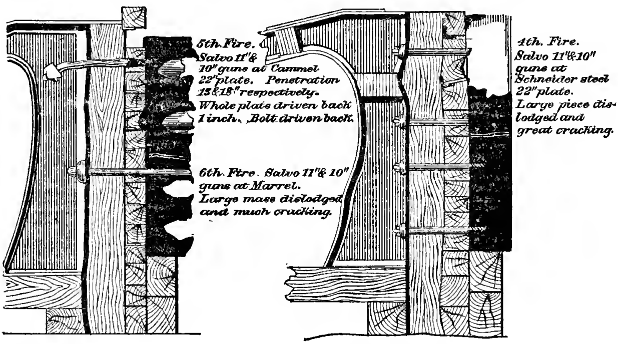
No. 4 was a sandwich target also in two divisions, the upper one being of Cammel iron similar to the upper Marrel of No. 3, and the lower one like the lower one of No. 3, except that the chilled cast plate was placed directly against the face-plate.

A fifth target consisted of two 22-inch iron Brown plates arranged similarly to target No. 1.

The guns used in the test were a 10-inch and an 11-inch Woolwich gun and the 100-ton Armstrong, full charges being used at a range of 100 yards.

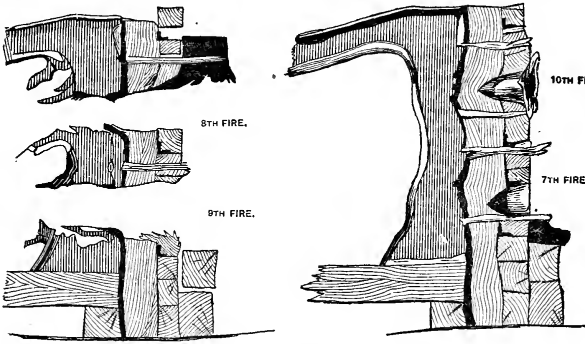


The first series of shots fired comprised one shot from the 10-inch gun against the Schneider, Cammel and Marrel plates. Shot No. 1 struck the Schneider plate fair and near the centre. At first no effect aside from a penetration of 10 inches was visible, but soon after a singing was heard from the plate, which continued for two or three minutes, during which time two cracks developed from the shot-hole, one running to the right edge of the plate and the other towards the bottom. Shot No. 2 struck the Cammel plate, penetrating 10.8 inches and developing two cracks, extending from a bolt-hole to the edge of the plate. Shot No. 3 struck the Marrel plate, penetrating 11 inches and making one crack from a bolt-hole to the edge of the plate.



The second series of shots fired comprised a single salvo of a 10-inch and an 11-inch gun against the same plates that were hit before No. 1 salvo, against the Schneider plate: both struck about three feet to the right of the centre of the plate, completely dislodging a piece from the upper right corner, opening the cracks previously made and starting fresh ones. No. 2 salvo, against the Cammel plate, struck near its edge, the 11-inch penetrating 13 inches and breaking up, driving one bolt in, lifting the upper part of the plate some inches above the top line of the target and making a crack from a bolt-hole to the edge. The 10-inch penetrated 18 inches and bulged the back of the plate. The whole plate was driven back one inch. No. 3 salvo struck the Marrel plate, breaking a large section completely out. The penetration was not as great as with the Cammel plate, and

the target sang quite audibly, showing that the plate was steely in its nature.



7th fire, 100 ton gun at Schneider Steel 22″ plate. Plate smashed to pieces, skin opened and bulged, target much shaken, shot broken up, the entire target driven 8 inches back.

8th fire at Camel Iron 22″ plate. 100 ton gun. Complete penetration. Half plate dislodged. Beams, knees, &c., broken.

9th fire, 100 ton gun at Marrel Iron 22″ plate. Complete penetration. Plate knocked into fragments.

10th fire, 100 ton gun at Schneider Steel 22″ plate. Plate already much broken, now completely destroyed, shot head bedded in backing.

The third series of shots fired comprised one shot from the 100-ton gun against each of the plates before attacked and one against the fresh Schneider plate. Charge, 340 pounds; projectile, 2000 pounds. Shot No. 1 of this series struck the fresh Schneider plate, knocking it to pieces and racking the backing severely, besides opening and cracking the skin. The entire target was driven back eight inches, but the shot was broken up and no part of it pierced the backing. No. 2 struck the Cammel plate and knocked half of it off the target. The projectile pierced the target, making a hole nearly four feet in diameter, breaking knees and beams and filling the rear with débris. No. 3 struck the Marrel plate, knocking it entirely to pieces and piercing the target. No. 4 struck the upper Schneider plate that had been hit by the lighter projectiles, destroying it and racking the structure considerably. As before, however, no part of the shot got through the backing.

The sandwich plates were next attacked with the same course of firing, with the general result that the 10-inch single shot pierced the face-plate. The salvo wrecked the face-plates almost completely, and the 100-ton gun projectile pierced the target easily.

The plates submitted by Brown & Co. were given the same test and acted about like the Cammel and Marrel plates, showing resisting qualities slightly superior to them, however.

The official report of the Italian Commission makes the following statement in giving judgment with regard to the comparative excellences of the several dispositions:

"Amongst the many problems to be solved in making the experiments at Spezia, the most important was that relative to the merits of the two principal types of armor tested; that is to say, the single plate and the sandwich systems. The types containing cast iron are eliminated from comparison, for having shown relatively feeble defensive qualities they were condemned unanimously and without hesitation.

"Between the two types above mentioned, the remarkable advantages realized with the single plates leave no doubt as to the superiority of this disposition over the sandwich.

"Independently of the indisputable fact that a sandwich target, when submitted to a relatively moderate shock, may be compromised in its system of fastening by the destructive effects produced in the interposed backing, it was determined that within the limits of the experiments several plates, superposed, having a certain total thickness, present relatively to a single plate much less resistance to penetration. Hence it follows that in the case where a projectile may not penetrate a single plate it may pierce entirely the superposed plates; and in the case where the damage produced by the explosion of a shell would be of but little importance in the single plate, it might, on the contrary, be very grave with superposed plates, for the shell might penetrate deeply before exploding, and consequently produce disastrous effects, like a regular mine in the frame of a vessel.

"It being then admitted that the preferable system is that of the single plate, of one of the various specimens presented for test, the next problem to solve is the following:

"Amongst the single plate targets tested, which should be chosen?

"To solve this problem we have, on the one side, three specimens of iron plates, and on the other one Schneider plate.

"In examining the qualities which go to establish the value of an armor plate, we give the three iron plates the following order of merit: 1st, Brown; 2d, Cammel; 3d, Marrel.

"But in considering that within the limits of power developed the defensive qualities of the three iron plates were about equal, since

none of them could stop the 100-ton projectile from complete perforation, whilst the Schneider plate did succeed, the question may be put under a more general aspect, and the comparison may be established between ordinary iron plates and Schneider ones, by enumerating for both the advantages and the faults determined by the tests.

"If we examine, in the first place, the iron plates, we recognize in them the following advantages:

"1st. The smashing produced on them by impact is more localized at the point of surface struck.

"2d. They behave better for relatively moderate impacts produced by projectiles of ordinary calibres.

"Against these advantages are the following faults:

"1st. Lack of continuity in the mass, arising from the difficulties of forging and rolling plates of such great thickness.

"2d. Relatively less tenacity than the Schneider, and consequently less resistance to penetration.

"3d. Absolute impossibility of preventing complete penetration within the limits of thickness given and power developed.

"The Schneider plates, on the other hand, show the following advantages:

"1st. Greater absolute tenacity and greater certainty of obtaining complete homogeneity in the mass.

"2d. More powerful means of producing plates of this metal. (This refers to the remarkable plant possessed by Schneider.)

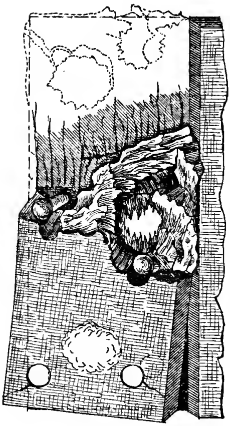
"3d. Greater resistance to penetration. Within the limits of the power developed the target may be depended on for protection against perforation.

"On the other hand the following faults may be imputed to it:

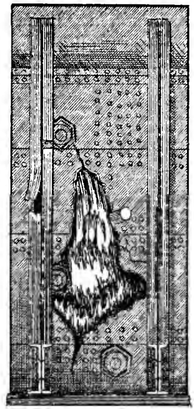
"1st. A crystalline structure of an aspect almost glassy, which renders the plates more easy to split even under shocks relatively feeble, and consequently

"2d. Greater ease of breaking in pieces and leaving the frame exposed.

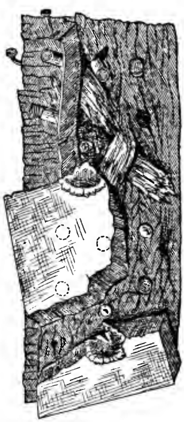
"This being established, in order to weigh and appreciate in a practical fashion the advantages and faults considered in such a manner as to deduce from them the true value of the two types to which the problem has been reduced, and to choose the most suitable for the end in view, we must examine what are the effects of a projectile which will do the most harm to a vessel.



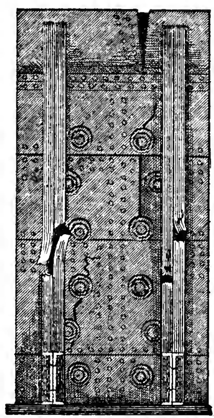
Cammel Target (Front)



Cammel Target (Back)



Schneider Target (Front)



Schneider Target (Back)

"The preceding experiments show us that if it is specially a question of heavy armor plates and a powerful gun, the three following effects have a tendency to be made manifest: penetration, rupture of the plate, and demolition more or less extended, according as the two first injuries are more or less great.

"If a projectile succeeds in completely piercing the side of a vessel an immense water-course is opened; if the breach is near the water-line very grave injuries are thereby caused, which, being of vital importance, are especially guarded against by the application of armor, and these injuries become still more disastrous if the breach be opened by a shell piercing and exploding inside. *A single blow well directed might suffice to disable an ironclad.*

"A projectile, on the other hand, which expended its work in breaking the plate struck and smashing the backing without piercing it may determine leaks, but they would be of less importance, could be easily counteracted, and their effects be circumscribed by the water-tight divisions. The flying splinters which otherwise would be produced inside the vessel would be eliminated, and although by the rupture of the plate hit, the backing might be entirely exposed, it is none the less likely that the chances would be against a second projectile hitting the backing already exposed.

"It appears then that the object which we have in view in seeking to protect the vital parts of a vessel against the power of ordinary guns, that is to say, to prevent perforation, is also that which suits best to put the vessel in the best defensive conditions against guns of the greatest power yet tested.

"Hence a vessel protected by the best iron plates tested would be in the conditions indicated by the first case, when it was hit by a projectile possessing at impact an energy almost equal to that which within fighting ranges would be developed by the 100-ton gun; whilst it would probably be in the conditions established by the second case if protected by Schneider plates.

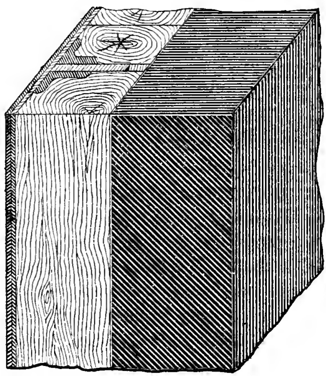
"Considering, on the other hand, the energy of guns actually used on vessels and in coast batteries, we may admit that a vessel would be thoroughly protected by either iron or Schneider plates, provided that the thickness was equal to that tested; but the local effects on the plate seem under these conditions to be most objectionable on the soft steel plates.

"From this aspect the use of iron plates would, therefore, seem preferable, but in looking ahead to the near future we can see with-

out a possible doubt that this relative advantage of iron is but temporary, and consequently of a nature to expose a vessel so protected to shortly lose her supremacy, which in the other case is assured in attack.

"*Consequently, after all these considerations, the commission has no hesitation in declaring and proposing as the most advantageous disposition, the single plate presented by Schneider.* . . . . We should prefer to use instead of the through-bolts the screw-bolts proposed by Schneider."

This judgment of the Italian Commission was severely criticized by the English press, and much capital was made of the *singing*,



Duttios' Armor.

cracking and complete breaking up of the Schneider plate, notwithstanding the indisputable fact that two successive shots from the 100-ton gun had failed to pierce the steel target, while all three of the shots at the iron targets had punched clear holes over four feet in diameter through them. It was true that the Schneider plate did not behave as well under the impacts of the 10 and 11-inch guns as the Cammel, but whereas these guns could not destroy the plate except after a great number of single shots or a very heavy salvo, thus modifying in a great degree its weakness in this respect, it was proof against any single shot from the 100-ton gun, which was not the case with the iron plate. Opinions with regard to this series of tests

seemed to be formed in the United States from the expressions of English daily journals which unhesitatingly condemned the Schneider plate, but this was not the opinion of English artillery experts, who, whilst pointing out the weaknesses of the plate, proceeded at once to benefit from the lessons taught. The armor chosen for the Duilio was acknowledged to be stronger than that of the Inflexible. Orders were at once issued for the manufacture and test of English steel and compound plates, which heretofore had given but moderately successful results. A new departure in armor manufacture was at once commenced, and as a result, the iron plates ordered for the turret of the Inflexible were put aside for compound plates which should more nearly retain the balance of power between the two vessels. In 1877 compound armor, from being comparatively unknown, had become popular; in 1878 it had become as it were the rage, and in 1879 iron armor had ceased to be recommended for English ironclads.

Much stress has been laid upon the matter of the revival of the racking and punching theories by these experiments, but the question rests upon an altogether different standpoint from that originally given it by the early wrought-iron tests. In the old times, the iron was poor in quality and of a brittle, hard nature.

As the quality of the metal advanced, or rather as the skill in iron manufacture increased, racking effects decreased, but penetrating effects *did not increase.* At Spezia, the Schneider plate was an excellent piece of metal, and it was really quite as *soft* as the iron plates, although its tenacity was much greater. Captain Orde Browne, R. A., in a lecture on armor, makes the following assertions with regard to the Schneider plate:

"There, steel had proved its incapacity to resist the fire even of small guns. Its remarkable property was, that in the act of going to pieces (which it invariably did), it had the power of absorbing the shock of a projectile which, according to calculation, ought to go through it easily. It was its remarkable power of distributing into its mass the shock of impact that stopped the shot and constituted the plate's power of resistance. On the other hand, armor that goes to pieces so readily under all circumstances by racking is of course open to grave objection."

Issue is taken with these remarks: 1st, with regard to the power of the steel to absorb energy in going to pieces. This is directly contrary to the laws of cause and effect. It is the projectile energy *which has been transferred to the plate* that causes it to go to pieces.

Its power to absorb energy is very small in the act of breaking compared with what it is while intact. Taking any corresponding shots on the steel and the iron plates, it is found that both had the same striking energy, and in both (taking the 10-inch single shots for example) this energy was completely destroyed in the projectile by the plate itself. The great penetration into the steel plate showed it to be soft in nature, so that the claim of brittleness cannot be made as it could in the early days of iron. The penetration was less in the steel than in the iron, therefore, under the supposition (which is true) that the projectiles were equal in strength, the racking effect on the steel must be greater than on the iron. This greater racking effect was mainly caused by the superior tenacity of the steel offering its greater resistance to tearing open. In the iron plate, the tearing commenced quickly and so followed a few lines of fracture. In the steel it commenced late, so that many lines were started at once as a greater extent of the armor was brought up to and past the tensile limit at practically the same time. The steel by no means *goes to pieces readily under all circumstances.* This was the case with the early iron, and was due to defects of workmanship and brittleness. If Captain Browne's argument be followed to a logical conclusion, and it be assumed that the hardness of the steel be increased whilst its other properties remain the same, then the same blow would shatter the plate much more, unless of course it be argued that the act of shattering absorbs energy, which cannot possibly be the case. In point of fact, however, in the experiments at Spezia in 1882, one of these Schneider plates having quite the same tenacity as the other one, but being very hard, received a projectile from the 100-ton gun with almost absolute impunity. The racking effects were all there as before, but before the strain could bring the many particles of the steel past their tensile limit, the hardness of the material had caused the energy to react fully on the shot itself and to be expended in breaking the shot instead of the plate.

It seems then more rational to attribute to steel the greater *inherent* resisting powers, and whatever defects the first Schneider plate may have shown, it seems indisputable that it exhibited powers of resistance that when properly developed would carry it far in advance of any description of wrought iron. This fault of going to pieces can be clearly made against steel proper such as is used in trade generally, which possesses a higher percentage of carbon and is capable of taking a high temper. Such material always has been and always will be

inferior to wrought iron as armor, and for the reason that Captain Browne states, that it goes to pieces readily; but with what are known as steel armor-plates, made of a very mild quality of steel, the argument will not apply at all.

In reviewing the period of the development of iron armor, from the date of the introduction of the rifle into the naval service as a substitute for the smoothbore, to the absolute end of iron development as determined by the introduction of the 100-ton gun, the following salient features are made plainly evident: In 1861, the armor disposition represented by the Warrior targets was actually invulnerable to all existing artillery, whether rifled or smoothbore. In less than two years from that time, the American 15-inch smoothbore and 8-inch rifle and the European 7- and 8-inch guns had destroyed the power of the 4½-inch plate. The attempt in the Minotaur disposition to increase the thickness of the plate whilst retaining the weight per superficial foot of target, the same as in the Warrior, proved a failure. The invention of Chalmers, consisting of introducing stringer plates in the backing, gave a new factor of resistance to armor, and, at the same time, the possibilities of manufacture advanced from 5 inches to 5½, thence to 6, and by 1867, good results are obtained with 8-inch plates. Meanwhile, the test of the Lord Warden and Flandre targets proved, beyond all dispute, the absolute necessity of stringer plates in the backing. With the Hercules target, armor development passes the guns and holds its own for a short time, but before the ship can be fitted out for her first cruise her invulnerability is gone. The limit in thickness of iron plates which the manufacturer can make with certainty halts at 12 inches, whilst the rapid development of gun-power demands far greater thickness. For a time, it is thought that the plate upon plate system will offer a solution of the difficulty; but, in application to vessels, the disposition is found to be impracticable, and a forced resort is had to sandwich armor. With this it is hoped to secure invulnerability, and the Inflexible is for a time regarded as a ship perfect in defence. Her side-armor is put in place with confidence, but scarcely is the last bolt driven when the 100-ton gun, speaking from the Spezia firing-ground, declares the day of wrought iron to be past. The English find out, too late to remedy the defect, that their own manufacturers could produce 22-inch solid plates superior to the sandwich armor of the Inflexible, although the steel plates of the Duilio were even superior to the solid plates. Again had an invulnerable ship been laid down, and been beaten before she could be launched.

V.

Steel and Compound Armor.

Although the Italian ships Duilio and Dandolo, whose armor was ordered in 1877, were the first ironclads of any account that were protected by armor of a different material from wrought iron, the commencement of the development of both steel and compound armor dates back as far as 1857, if not earlier. That material which in armor-plate manufacture is now called by the general term of steel, was, until a few years ago, divided into two classes, called respectively steel and homogeneous metal. The class recognized as steel contained scarcely ever less than one per cent. of carbon,—sometimes, however, falling as low as three-quarters of one per cent., and the metal was practically distinguished by its power of *receiving a temper*, combined with very high tensile strength and elasticity. The name of homogeneous metal was given to a description of metal falling between steel and commercial wrought iron, which, although known of and used for centuries, first received its distinct commercial classification from a patent issued to the English firm of Shortridge & Howell, shortly after the introduction of Bessemer steel. It contained from $\frac{1}{3}$ to $\frac{3}{4}$ of one per cent. of carbon, and, whilst it would not take a decided temper, thus falling out of the early category of steel, and possessed the faculty of sustaining bending and twisting strains like wrought iron, it had a much higher tensile strength and elasticity than that metal. As knowledge developed with regard to the finer points of distinction between steel and wrought iron, this metal came to be known as semi-steel, and finally, as its good qualities became developed, as mild steel. This is the description of metal of which what are now known generally as steel armor-plates are made, as well as the facing of compound plates, and it is necessary in tracing the development of these armors to keep in mind the distinction between what were termed steel plates in the early days and those of the present time.

In 1857 the Woolwich authorities invited English iron-workers to submit both iron and steel plates for test by heavy guns. A Mr. Begbie, who had invented an especial method of producing plates

from puddled steel, submitted a number of 2-inch plates, which broke up badly under the 68 pdr. During the experiments a test was made against a 4-inch iron plate, over which was *fastened* a 2-inch steel plate, the whole being bolted to a 24-inch backing; and it was found that the 68 pdr. wrought-iron shot could get through the combination at a range of 400 yards. The general test was considered to have shown that steel was quite unfit for armor.

In 1859 the Mersey Iron Works submitted a number of 2½-inch plates for test which were made up of three layers of equal thickness, the outer ones being of wrought iron *welded* to a centre layer of steel. These plates proved to be quite poor, as the welding was very imperfect, and the brittleness of the layer of steel affected the other layers. A number of 3-inch puddled steel plates were tested at Portsmouth the same year, and although the penetration of the 68 pdr. was considerably less than with iron plates, they broke up badly.

In 1861 an extended and important series of tests was made by the "Iron Committee" with wrought iron, homogeneous metal, and the above-mentioned Mersey compound plates. Howell & Shortridge's metal and the Mersey combination proved to be very poor and took rank last in the scale of efficiency. During this period (1857-61) a long series of experiments with steel had been carried on at Vincennes, in which all the prominent continental iron-workers were brought into competition. Krupp, Begbie, Petin et Gaudet, and the manufactories of Allevard and Bochum were represented; but invariably the steel was found too brittle to be of service, and apparently the French condemned it, as for a number of years after 1860 no notable experiments were carried on. It has been stated in a former chapter that in the earlier years of armor development French wrought-iron plates were superior to English ones. It was very generally believed in England that French plates were not in reality pure wrought iron, but that they contained a steel centre layer, and it was almost solely on this account that the Mersey Iron Works made repeated efforts to manufacture acceptable armor of this kind. It was afterward found, on submitting French plates to chemical analysis in England, that the percentage of carbon was, if anything, lower in French than in English plates, the superiority lying principally in the greater perfection of manufacture.

In the evidence of the witnesses called before the English Iron Committee in 1861, the advantages of compound and steel armor appear to be abundantly set forth. It was the general opinion that

the best *available* material for armor plates was the softest wrought iron; but many of the prominent witnesses, as well as the committee itself, did not consider by any means that this metal furnished the final solution of the question. Thus, in the evidence of Mr. Bessemer is found the following:

"Question by committee. It has occurred to the committee as well worthy consideration, whether a perfectly ductile iron could not be combined with a certain thickness of steel on the exterior to resist the force of impact in the first instance, and yet retain all those properties which you now describe with regard to its toughness.

"Answer. I believe that would be a very valuable modification of the metal, and I think it is quite capable of being produced; indeed, I have contemplated its production for two or three special articles, such as the manufacture of anvils, with which I need not trouble you. To return to your question, if we convert in two separate vessels four or five tons down to a state of the softest malleable iron, and convert four or five tons to the state of soft tough steel, or steel approaching ordinary steel in hardness, there would be no difficulty in allowing the metal to flow from one of those vessels into a cast-iron mould; the solidification takes place so soon that the upper surface would remain only a small puddle some four or five inches in depth; if, immediately you have got the whole of this tougher metal in the mould, you commence to pour the harder metal upon it, there will be a point of union between the two in which the soft metal would imperceptibly pass into the harder quality, and filling up the mould to the required depth with a harder metal would give you a mass when hardened, the upper stratum being of the harder quality, which you require, and the lower the softer quality, the two not being united by any welded line, but by the two qualities gradually and imperceptibly passing one into the other, so that there would be no likelihood of separation or of any violent strain from difference of expansion and other circumstances of that kind; it would be a perfect union and not a weld."

Mr. Lancaster stated that the best armor plate should consist of three layers made in the piling; the outer surface should be of soft iron, and the inner, or core of the plate, of steel, or like hard material, and the innermost portion should be tough fibrous metal.

Mr. Menelaus considered that the best material to use would be semi-steel, produced by the puddling process, or a mixture of steel or semi-steel coated with soft, tough iron.

Colonel Lefroy was opposed to steel for armor, but considered homogeneous metal as the best.

From these opinions it is seen that even in these early days of armor development, and notwithstanding the excellent results already obtained from wrought-iron plates, other metal was considered to be better. Some advocated homogeneous metal throughout (or the present steel armor), others preferred a combination of the semi-steel and wrought iron. In some cases it was thought that the different metals should be welded, and in others that it should be combined; either on the plan suggested by Bessemer, or by oil-tempering the faces of plates and annealing the backs. Some preferred the iron part in front, some in the centre and some at the back.

In January, 1863, Shortridge & Howell submitted a test-plate, which was called a "compound" plate in the report of the Iron Committee. This was manufactured in the following manner. A number of iron bars, heated to a welding heat, were placed upright in a mould and well sprinkled with a flux to remove cinders; the mould was then filled with molten homogeneous metal and the mass was worked under the hammer to a 2½-inch plate. In this way the plate was what might be called in streaks of iron and steel instead of in layers. The plate was tested with the Armstrong 40 pdr. at 100 yards, and the report on the experiment states that "The plate was an improvement on former plates (made entirely of homogeneous metal) supplied by Messrs. Shortridge & Howell, but this is probably due to the wrought iron bars forming the core of the plate; the committee, however, do not consider the plate equal in its power of resistance to a good wrought iron plate of the same thickness."

Amongst the armor proposals submitted to the committee was one by a Mr. Cotchette, as follows: "Upon an armor-plate, say 3 inches thick, weld a surface of blistered steel ¾ of an inch thick; or 'convert' to a depth of ¼ of an inch, the face of an armor-plate 3½ inches thick, the plates being subsequently passed through a pair of rolls for consolidation and to reduce the blisters. The face of the plates could then be hardened."

In March, 1863, a compound plate was submitted for test at Shoeburyness by a Mr. Russ; it being made up of a 3-inch soft iron plate, faced with 1½-inch steel welded on. A single shot from a 40 pdr. Armstrong broke it in two.

In 1864 an extensive series of experiments was carried on in Russia with guns, projectiles and armor, and amongst the plates pre-

sented were samples of steel from the Thames Company, Brown & Co., The Parkgate Company, and Petin et Gaudet. One of these $4\frac{1}{2}$-inch steel plates was tested with a 68 pdr. smoothbore by firing three shots equally spaced along the middle horizontal line. The penetration was found to be less than with wrought-iron plates, but when the plate was removed from the target it was found that directly in the rear of the points struck it was broken in several pieces, besides which there was a through-crack the entire length.

Mention has been made in a former chapter of the great difference of effect produced by projectiles of any given size, shape and weight, but differing in material. Fairbairn, it will be remembered, classed the efficiency of cast, wrought and steel projectiles in the ratio of 1 to 2:6 to 3. In 1866 the Palliser chilled projectile was introduced in England, and about the same time the Gruson chilled projectile appeared in Prussia. In spite of the many shortcomings of the first shot, they were found to be fully equal to the steel ones then used in penetrating power and were soon developed to a superior position. The great objection to the steel shot had been its great cost, but the chilled projectile completely overcame this drawback; the increased penetrations obtained forced a decided increase in the thickness of wrought-iron armor; to so great an extent in fact as to surpass the carrying power of ironclads of from 6000 to 8000 tons displacement, which was the average size considered as best for the fighting, sea-going ships. In order to meet the new difficulty, which bid fair to strip ironclads of their armor, it was determined in England in 1867 to make another trial of iron and steel combined; thus showing that the opinion was still held that true development lay in this direction. Invitations were sent out to the prominent English iron-workers to submit plates for test, and a good response was met with. The first firm to appear was Cammel & Co., who submitted in March of that year a 7-inch plate composed of alternate layers of iron and steel *welded* together. This plate was submitted to a test with the 68 pdr. and the 7-inch rifle, and it showed a resistance scarcely equal, in so far even as penetration was concerned, to good wrought iron, and broke up rapidly in all directions. The result of the combination showed all the faults of both iron and steel without any of their benefits. Two months later, the other firms having responded, a series of tests was made with a number of 7-inch plates, using the 7-inch Woolwich rifle and Palliser projectiles at a range of 70 yards. The plates were made up as follows:

A—Cammel & Co.—4½-inch iron faced with 2½-inch steel.

B—Cammel & Co.—3-inch steel centre plate with 2-inch iron face and back.

C—Cammel & Co.—Four welded plates of alternate 1¾-inch iron and steel.

D—Cammel & Co.—A single 7-inch iron rolled plate.

E—Brown & Co.—4-inch iron, faced with 3-inch steel.

F—Brown & Co.—Similar type to plate B.

G—Brown & Co.—A single 7-inch iron rolled plate.

H—Mersey Company—A single 7-inch iron rolled and hammered plate.

The results of the firing classified the plates in the following order of merit. H, D, A, G, E: with B, C and F about alike and inferior to the others. Two points in these tests deserve special attention: 1st. the high position of the A plate in the classification, which scored *the first success for a compound plate:* 2d. the fact that all the plates *faced* with wrought iron failed completely. No especial importance was at the time attached to this latter result, but, as will appear, it proved to be a most important point, shedding great light upon the action of projectiles on armor and developing a most curious fact in this connection,

In 1874 Sir William Armstrong experimented with a new style of steel plate, the experiment and result being spoken of as follows by Mr. Stuart Rendel, who was then attached to Armstrong's establishment, and who now is a member of the Admiralty: "Armstrong having observed the great increase in the tenacity of steel caused by oil-tempering, made and tested an oil-tempered plate. Preliminary statical experiments, made with test-pieces from this plate, gave to it qualities of hardness, ductility and tenacity much superior to wrought iron, independently of the other advantages possessed by steel; but when this plate was submitted to the firing test it was cracked by the first shot and broken to pieces by the second.

"Inexplicable as the fact is, it proves that steel resists a statical pressure better than iron; but, on the other hand, it offers much less resistance than iron to impact, notwithstanding the fact that it shows a remarkable ductility under ordinary tests. Therefore, steel is inferior to iron for certain special uses, aside from its defects of blow-holes and faults which forging will not completely remove from it. . . . None of our vessels of war have been provided with steel boilers. It is superfluous to add that none of them have received steel armor."

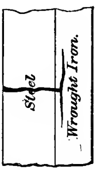
This opinion was rendered by one of the highest authorities on metal-work in Great Britain, and yet within a year from the date of its emission, steel armor had fairly beaten wrought iron, at Spezia, in the most severe test to which armor had been submitted up to that date. Within two years steel boilers had been designed for English war-vessels, and within six years Rendel himself was engaged in building a steel war-vessel, with steel boilers and steel deck-armor. There is not the slightest doubt that Mr. Rendel had what appeared to be the most positive practical evidence in favor of his assertion of the limited applicability of steel; but had he weighed carefully the evidence of the rapid development of steel manufacture in all branches of construction since the time when Bessemer's invention had brought the cost of production within practical limits, he would scarcely have implied quite so sweeping a condemnation.

In 1876 the experiments at Spezia took place, which resulted in the *first decisive victory of steel over iron;* and at this point it is necessary to again call especial attention to the nature of this steel. The plates of the Spezia target were made of what was called "Schneider metal," and it was described as being *steely iron.* In point of fact, leaving out of consideration the especial method of fabrication, which only developed to a high degree the inherent qualities of the metal, these plates were simply homogeneous metal, or semi-steel, or mild steel,—according to the local distinction given to the still unsettled classification. The plates deserved to be called by the distinct title of Schneider metal just as the distinction is made between Bessemer steel and Siemens-Martin steel, the expression denoting more a distinction in method of manufacture than in absolute chemical constitution. Turning for the moment from armor construction to shipbuilding, it will be found that at this time the same indistinctness was evident in the classification of metal for ships and boilers. Authorities in iron-working will be found at this time insisting that those plates containing a very limited percentage of carbon were not steel at all, but only a species of wrought iron. On the other hand, the steel enthusiasts will be found insisting that the metal was purely steel. As finally determined, the metal was called steel, and many of the arguments with regard to the Spezia experiments will be found erroneous, simply from the fact that as one side or the other called the plates steely iron or mild steel, they lost sight of the fact that the metal stood at the boundary between iron and steel, and they reasoned from absolute qualities belonging exclusively to one of the two distinct types.

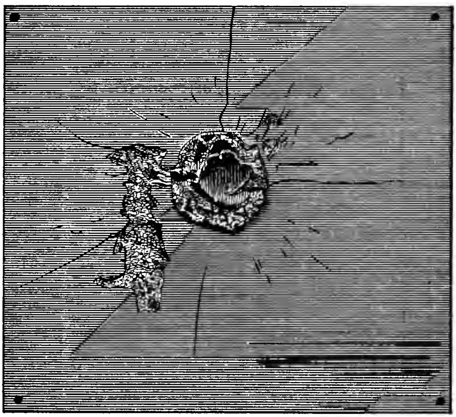
The Schneider metal was of a very soft description, as was evidenced by the deep penetration of all the projectiles which struck the plates; corresponding in this respect quite closely with the penetrations into the iron plates. Of all the reports and arguments written with regard to these experiments, the official report of Lieutenant Pecci, of the Italian artillery, seems to approach closest to the actual facts of the working of the projectiles. His argument was, that in all experiments previously made on wrought-iron plates, the thickness was such, that the energy, or rather the factor of velocity was sufficient to carry the projectile through the plate without either splitting it or tearing it from the target. In the Spezia trials, however, the new element of great thickness was introduced in all the plates. An examination of the fragments of plate, and of the targets themselves, showed that there was really no complete perforation of the Schneider plates, and probably not of the iron plates either, by the projectiles from the 100 ton gun. Penetration seemed to stop at a certain depth of plate, but in all cases the latter was broken in pieces and torn from the target. The fragments of steel were many and the backing was not pierced, whilst the fragments of iron were few and the backing was pierced. The effect of the projectile then, generally speaking, consisted of, 1st, a *penetration* similar to that produced in plates of less thickness; 2d, a *rupture* of the plate, due either to the wedge-like action of the projectile, or to the molecular actions set up by the violent shocks. The plate must then oppose, 1st, a resistance to penetration which, for a given instant of penetration, where the projectile has still a given velocity (at least within certain limits), is an increasing function of the *quantity* of penetration; 2d, a resistance to rupture which, for a given penetration and a given velocity, is a function of the tenacity of the metal and of the position of the point of impact relatively to the exterior contour of the plate. When at a certain moment of penetration, while the projectile still possesses a considerable energy, the rupturing effect becomes greater than the penetrating, the plate breaks and a part or the whole of the force of the shot is absorbed in this work. If but part of it is absorbed the projectile still acts on the backing; if all of it goes, the backing remains intact.

The results of these experiments created a great stir in English professional circles, and the development of compound armor, which had heretofore been carried on by a few manufacturers with but little encouragement, became suddenly forced upon the Government.

The opponents of steel, who had previously considered in their discussions only the hard-tempered material, had their eyes opened to the fact that it would no longer do to split hairs over a name. This material had suddenly become to England a most disagreeable fact, and whilst it might still be left to scientific societies to squabble over the terms homogeneous metal, semi-steel, mild steel, and Schneider metal, it behooved those upon whom the responsibility of development rested to work it up immediately. Early in 1877 the Woolwich authorities invited the submission of steel and compound plates for test at Shoeburyness, and in August of that year the first of what are now known as compound plates was tested.



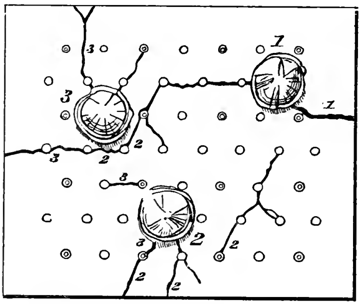
View of top edge of plate showing crack made by impact of shot.



First Cammel Compound Plate.

It was submitted by Cammel & Co., and had been manufactured under the patent of Mr. Wilson, the superintendent of that firm. The plate was made up of 5 inches of iron, with an additional 4-inch face of steel. Instead of following the earlier practice of making the two plates separately and then welding them together, the iron plate was first rolled, then raised to a welding heat, and the molten steel for the face was poured on top. The great heat of the molten metal partially fused the iron contact-face and thus joined the two metals without welding, although the plates were put through the rolls almost immediately, thus combining the whole mass thoroughly.

This plate was tested with the 7-inch rifle at 25 yards range with a Palliser projectile. The depth of penetration was but $3\frac{1}{8}$ inches, whilst if the plate had been of iron it would have been fully 8 inches. A patch of the steel face was also knocked off, presumably by a piece of the projectile after it broke up. Radiating cracks were found around the point of impact, but they were only the depth of the steel face, the iron part being uninjured. This result far surpassed all expectations and steps were at once taken to develop the system. In December, 1877, a competitive test (now generally known as the first Nettle experiments) took place with plates of 9 inches thickness, of various fabrications. They consisted of:



Whitworth Plugged-Steel Plate.

1st. A Whitworth steel plate, untempered, and reinforced in a peculiar way by being, as it were, pitted with plugs of very hard steel, inserted in the plate after it was finished. Wherever bolts were inserted the holes were bored through these plugs.

2d. A subcarburized Cammel steel plate (a new name for the mild steel) containing $\frac{13}{100}$ of one per cent. of carbon.

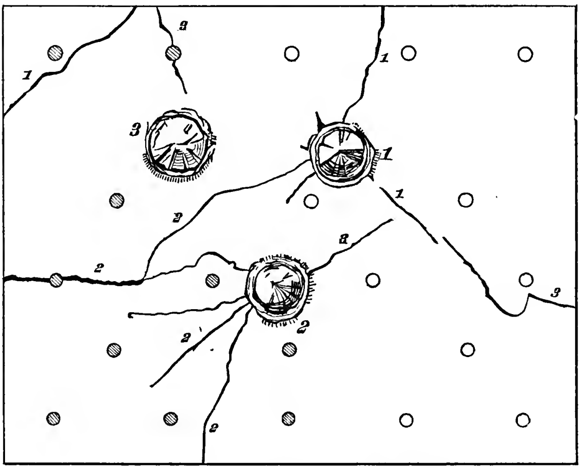
3d. A Cammel compound plate made up of a steel plate $6\frac{1}{2}$ inches thick, with an iron face $\frac{3}{4}$ inch and an iron back $1\frac{3}{4}$ inch. In this case the plates were plain welded together, the steel one containing $\frac{57}{100}$ of one per cent. of carbon.

4th. A Wilson compound plate of the new method of manufacture, made up of an iron plate of 4 inches, with a 5-inch steel face containing $\frac{64}{100}$ of one per cent. of carbon.

5th. A 9-inch wrought-iron plate of the best manufacture, which served as the standard of comparison.

Three shots were fired at each plate with a 9-inch rifle at a range of 10 yards, with the following results :

Plate No. 1.—None of the projectiles pierced the plate. The head of the shot in every case remained imbedded in the plate, so that the actual penetration could not be measured. It was estimated at not over 4 inches. Each shot developed cracks on the plate which were opened out by the succeeding ones. At the last shot one of the plugs was thrown out.

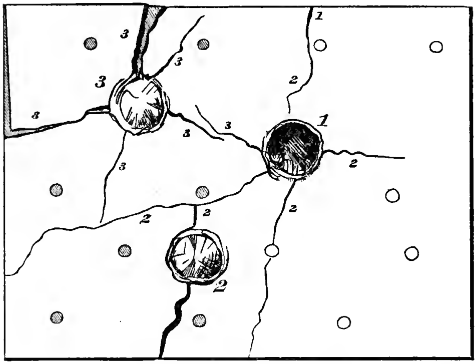


Solid Steel Plate—"Subcarburized".
Cammell's Patent 9'.9"x7'.9"x9" thick.

Plate No. 2.—Same effect as with the Whitworth. The penetration varied from 2¾ to 7 inches. Cracks were developed, but no part of the plate was knocked away.

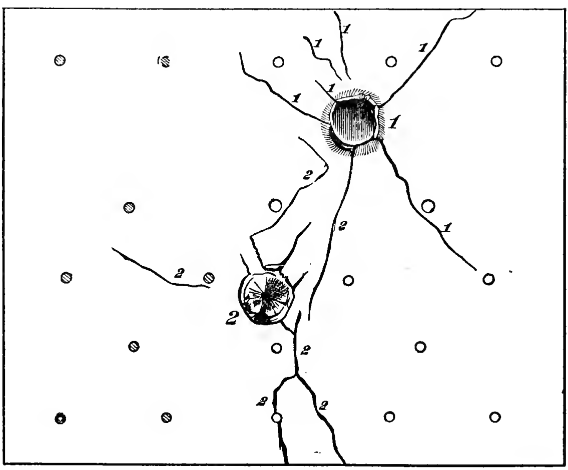
Plate No. 3.—Same effects as the preceding, but the plate was opened more in the cracks. One of the upper corners was knocked completely off the target. Penetration almost the total thickness of the plate.

Plate No. 4.—The first projectile penetrated so deeply that its base was 1¾ inches beyond the front face of the plate. It was estimated that the total penetration was about 24 inches. The plate was thus



Combined Iron and Steel Plate.

Hard Steel between two layers of Iron Armor Plate. A. Wilson's Patent.



Combined Iron & Steel Plate. Hard Steel on Iron Armor Plate. A. Wilson's Patent. 9′.9″ x 7′.1½″ x 9″ thick.

entirely pierced, together with a considerable part of the backing. Radiating cracks were started about the shot-hole. The second shot stuck in the plate without piercing it, producing several serious cracks. These results were so unsatisfactory that the third shot was not fired, the steel seeming to be of bad quality.

Plate No. 5 behaved in the manner customary with good iron plates: the three projectiles pierced it completely without starting any cracks at all. Two of the projectiles were checked up well by the backing, but the third got well in, giving a total penetration of about 22½ inches.

In these experiments the Whitworth was at a disadvantage, as it was smaller than the others and was not manufactured in accordance with Sir Joseph's desires. It was made from a solid ingot hammered to shape, his intentions having been to have cast a hollow cylinder of fluid compressed steel, cut it through and opened it out, and then tempered it in oil. Even with these drawbacks, however, it stood well up to its work, and came out a clear No. 1 in order of merit. The subcarburized plate took a good second place in the contest, in spite of its horrible name. In this test, the first one ever made where steel and compound plates of the new development were tried in competition, the steel ones were victorious.

In February, 1878, this series of experiments was continued with two compound plates furnished by Brown & Co. The mean penetration of three shots into one of the plates was 10 inches, the plate showing twelve cracks, some of which extended clear through the plate. The two first shots on the second plate gave a mean penetration of 9 inches and started cracks; the third shot knocked a large piece of the plate completely off the target. Both plates were bulged at the back about 8 inches.

Shortly afterward two other compound plates were submitted by Brown & Co., made under the patent of Mr. Ellis, the Superintendent of that firm, which differed from the Wilson patent in several particulars; the principal of which were, that Bessemer steel was used instead of open-hearth, and the molten steel was run on the iron plate while the latter was in its heating-furnace instead of after it was withdrawn. The face of one of these plates was hard and that of the other was soft. The shots on the soft plate penetrated 12 inches, starting several cracks, most of which were only the depth of the steel face. The penetration into the second plate was 11 inches, making deeper cracks than the first. At the last shot a piece of the plate was knocked off the target.

In May, 1878, Cammel & Co. submitted two *steel* plates (9-inch), one being oil-tempered and the other of soft steel. The oil-tempered plate broke down at the second fire. The first shot on the soft plate penetrated 7 inches and split it from one side to the other. The two other shots pierced it completely.

Next a Cammel 9-inch compound plate was tested, five shots being fired at it instead of three, as heretofore. Of the three first shots, but one barely pierced to the backing, and the cracks were quite superficial; the fourth, fired at the centre of the triangle formed by the previous impacts, broke the plate into two sections. Finally, the fifth shot completed the destruction of the target.

Shortly afterward, Whitworth submitted a new steel combination formed of a series of hexagonal sections, each one composed of concentric rings surrounding a circular central disc, the whole being made of fluid compressed steel. By this disposition he proposed to stop the long cracks, limiting them to the individual discs struck by the shot. The 9-inch plate of this system was tested with a 9-inch gun, a single shot being fired. This shot was broken to pieces without producing any other effect on the target than to make an imprint 1½ inches deep and 8 inches in diameter. The disc struck out was not cracked and the rear of the target showed no signs of weakness. This test was officially declared to have demonstrated the excellence both of the disposition and of the Whitworth compressed steel.

Reference was made in the last chapter to a lecture delivered by Captain Browne, R. A., on armor, and as in that lecture reference was made to the results of the "Nettle" experiments, it is quite pertinent to quote from the conclusions drawn, as they expressed the opinion prevailing at that time in England with regard to compound armor, and which it is believed is still the opinion of perhaps the majority of those interested in the development of armor. Captain Browne says:

"The question naturally arises whether the peculiar properties of the compound plate may not be sacrificed by the natural tendency to prevent cracking by softening the steel and so compromising the character of the target. The best idea seems to be that of a hard steel surface which will crack to pieces, but is prevented from actual separation by adhesion to a thickness of wrought iron sufficient to hold it together. The problem to be solved is, how best to find a harmless form for the work done to take. If it could be proved that a given quantity of work stored up represented actually a smaller injury in

one kind of metal than another, then so much would be gained; but a claim of this kind has scarcely been attempted to be made for steel on any results achieved. The hope is rather to force the work to take some form which the target may bear than to decrease the injury in actual quantity. When it is considered that the blow of the shot of the 100-ton gun represents an amount of work stored up which is sufficient to lift a turret weighing 300 tons to a height of 78 feet, it will be seen how difficult it is to provide for the absorption of so vast a shock."

It is undoubtedly true that an attempt to prevent the cracking of a steel plate by softening its surface would compromise the character of the armor seriously, as will be shown by example farther on. But it is believed that this cracking was treated erroneously by the English experts at this period. Captain Browne asserts that it is best to accept *the hard steel surface that will crack to pieces.* This certainly is a dangerous doctrine—to assume that *with mild steel* such an evil must be accepted. The Whitworth steel plates already mentioned cracked much less than any of the compound plates, and the very slight penetration in the last case showed a great surface hardness. It would seem that since practice had shown that hardness in mild steel was not necessarily accompanied by great brittleness, the best line of development is *to accept the hard steel surface that will not crack to pieces.* The moment that this point is reached the necessity for the wrought iron accompaniment ceases. Captain Browne holds that a given quantity of work stored up does not actually represent a smaller injury in one metal than in another, which is equivalent to saying that the difference in penetration into wrought iron and steel armor is exerted and shown in the cracking or racking of the target. This is certainly the *tendency*, but by no means the actual effect. In the Spezia trials it may have been the case, but the evidence of the Whitworth trials upsets that theory, for not only was the penetration less, but the whole racking effect was less also. He states that it is the hope to force the work to take some form which the target may bear rather than to decrease the injury in actual quantity. This assertion is not borne out by experiment either, for from the very beginning it was sought to decrease the injury in actual quantity by forcing the energy to work destructively on the projectile instead of the target. It was this reduction which forced cast-iron and then wrought-iron projectiles out of use, and to-day steel projectiles are forcing chilled ones out on the same principle. The confusion still existed as to the

respective characteristics of mild and true steel. The latter had proved repeatedly that it could not be hardened without jeopardizing it on account of brittleness, but mild steel can be hardened without increasing brittleness to a dangerous extent. Whitworth metal has repeatedly shown to what a high degree surface-hardness and tenacity combined may be carried. Other methods of steel manufacture have not as yet reached this high condition of development, but it is within the limits of possibility; and experiments on steel armor show a constant although slow approach to the desired end.

In 1878 a comparative test was made of the effects of projectiles fired against the face and then against the back of a compound plate. It was found that when the chilled shot struck the face of a plate it was smashed to pieces, with but a slight penetration; whilst when it struck the iron back it pierced the plate completely. This astonishing result gave rise to innumerable theories; and since in looking back at the results of experiments made before, it was found that plates faced with iron had invariably been pierced, another experiment was tried by taking a compound plate and attaching to it a thin wrought-iron plate over the steel face. It was found that the addition of the plate enabled the shot to get considerable increase of penetration. Another test was then made by putting an iron jacket over the point of the shot, which gave the same result of an increased penetration.

Of all the ideas expressed on this subject the most reasonable seems to be that which attributed the phenomenon to the support given to the shoulder of the projectile by the surrounding medium; which, although checking penetration to a degree, gave still more aid to the cohesive force of the molecules of the shot, enabling them to work together and concentrate their energy on the point. From this it would seem, as just stated, that the true development of armor was in the direction of hardening the face, in order to make the energy of the projectile work destructively on the shot itself, and by breaking it to pieces so enlarge the area upon which the energy acts that the metal of the plate can support the shock. On the other hand, the true development of the shot is to substitute steel for chilled iron in order to get a metal that can better resist a sudden shock, and then to lengthen the point by striking the contour of the head with a longer radius in order to get a form which enables the rear of the shot to act to greater advantage on the point. In point of fact, this is the actual development of to-day. The faces of armor plates are growing harder, whilst the liability to crack is not increased, and steel projec-

tiles are now replacing chilled ones, whilst the radius of the ogive of the head has increased from 1½ diameters to 2 and even 2½.

In April, 1878, a very complete series of experiments was carried on at Shoeburyness to test the comparative excellence of chilled-iron and steel projectiles. The 9-inch gun was used and the targets were unbacked 12-inch wrought-iron plates, which on this occasion were hung on trunnions. It was found that at every shot the plate was thrown completely out of its seat before it had time to oscillate. The results obtained may be concisely stated as follows:

CHILLED CAST PROJECTILES.

Gruson—Penetration 8½ inches, shot broke up.
" Pierced, shot broke up.
Krupp—Penetration 10½ inches, shot broke up.
" Pierced, shot broke up.
Finspong—Penetration not obtained. Projectile stuck in the plate unbroken.
Finspong—Pierced, head of shot broken.
Gregorini—Penetration 10 inches, shot broke up.
" " " " " "
Palliser—Almost through, shot broke up.
" " " " "
" " " " "
" Pierced, shot broke up.

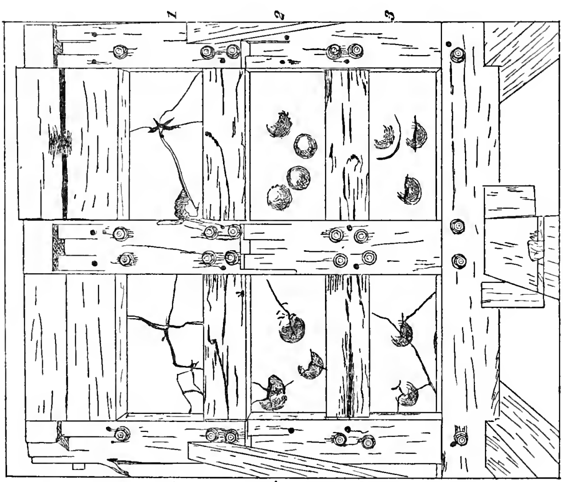
STEEL PROJECTILES.

Terre Noire—Penetration 8 inches, shot not broken.
" " Penetration 10 inches, shot not broken.
Whitworth—Pierced, shot not broken and hardly deformed.
" " " " " "
Hadfield—Almost through, shot somewhat broken.
" Penetration 9½ inches, shot somewhat broken.
" Penetration 10¾ inches, shot not broken.
Landore—Penetration 9½ inches, shot broken up.
" " " " " "
Vickers—Penetration 10½ inches, base of shot broken.
" (steel with chilled iron point)—Penetration 8½ inches, shot split.
Cammel—(steel with chilled iron point)—Pierced, point broken.
" " " " " "

The Whitworth projectiles came out of this contest far ahead of the others, whilst the Terre Noire steel stood a good second. Shortly afterwards an important series of comparative tests of steel and chilled projectiles was carried on in Russia, resulting in a proof of the great superiority of steel shot made by the Terre Noire process over all other kinds. (The Whitworth metal was not represented in this contest.)

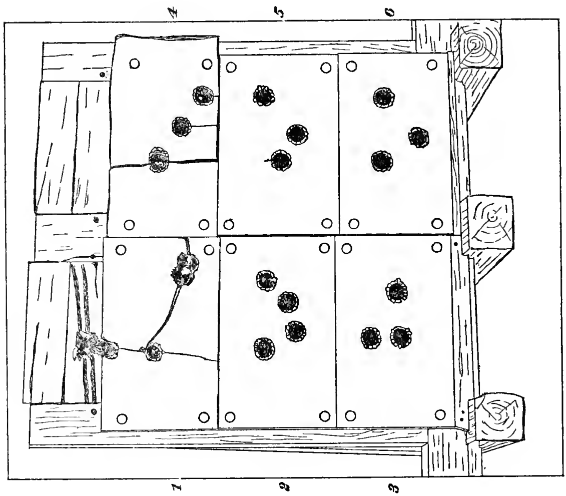
During the months of July and August, four test plates from the lots intended for the Inflexible's turrets were tested. These plates were 9 inches thick; made up of 5½ inches of iron, with a steel face of 3½ inches, furnished by Cammel & Co. The gun used was a 9-inch, and three shots were planted on each plate, the penetration in no case reaching the iron; and whilst cracks were formed on the steel face, they did not extend as far as the iron. The progress in development of compound armor had been marvellously rapid, and this test, made on plates taken at random, serves well to show to what a state of certainty the manufacture had arrived. The projectiles used, however, were of Palliser chilled iron, which did not measure the full power of the gun; or, rather, which wasted an important factor of energy by breaking to pieces on impact.

The importance of this feature was very well shown at Spezia in July, 1879, where projectiles of different manufacture were tested against 28-inch Terre Noire steel plates. The plates unfortunately proved to be very inferior in quality, and the gun having been chambered so as to hold an increased charge, no direct comparison can be made between the results of this test and the one made in 1876. The plates rested against a backing of 20 inches, but were not bolted to it, the whole target being braced in rear by struts and beams arranged like the frame of a vessel. The first shot fired was a Gregorini chilled one, which broke the plate. The shot itself was smashed to pieces, some of the fragments flying 10 feet to the rear. The total penetration was 15 inches. The second shot was of Whitworth compressed steel, and it pierced the whole target, breaking the plate. From the looks of the fracture the shot seemed to have penetrated about 23 inches before the plate commenced to break up. This shot was scarcely deformed at all, the ogive being slightly swelled out, but the point being as sharp as it was before firing. The third shot was of Armstrong forged steel. It penetrated 13½ inches and broke the plate, but the shot was very badly bulged and deformed. Thus, of the three shots, the Whitworth alone utilized all its energy on the



Back of Target.

1. Terre-Noire. 2. Creusot. 3. Marrel (iron.)



Front of Target.

4. Landore. 5. Krupp. 6. Marrel (steel.)

COMPETITIVE TEST-PLATES FOR THE TORDENSKJOLD.

target, showing that the gun was capable of piercing it completely. The other two could not get in any injurious work on the backing—the one on account of breaking up and the other by becoming deformed.

The Danes having built a large torpedo-ram (the Tordenskjold), determined to give her a steel deck-armor, and issued invitations to all the prominent steel works to submit test-plates. In June, 1879, five plates were received in response to this invitation, together with one iron plate, which was to serve as a standard of reference. The contesting firms were those of Landore, Marrel, Creusot, Krupp, and Terre Noire. The plates were all 3½ inches thick and they were bolted by the four corners to open target-frames, so as to be entirely unbacked. The gun used was a 3½-inch Krupp, firing a Krupp projectile made from Bessemer steel. It is well worth mentioning, that of all the shots fired none of the projectiles were broken or deformed, so that a most exact comparative test of the resisting powers of the plates was obtained. Three shots were fired at each plate, and the Creusot plate having shown no cracks or signs of giving way at the third shot, had a fourth fired at it, which it withstood as well as the others.

The report of this test states as follows:

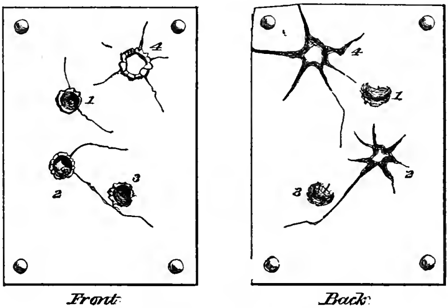
"The Terre Noire, Landore, Krupp, and Marrel steel plates showed about the same resistance. They were not pierced by any of the projectiles. The metal of the plates was *turned back* at the point of impact all around the shot-holes; cracks were made on the rear of the plates connecting the bulges and extending to the edges of the plates. The Terre Noire and Landore plates also had cracks on the face of the plate. Those of Krupp and Marrel were less seriously injured.

"The Marrel iron plate was slightly inferior to the above. It was almost completely perforated by one shot; but the effects of all the shots were more localized, and no cracks appeared at the bulges on the back.

"The Creusot plate showed qualities much superior to the others. Although it received four shots, the bulges on the back were very slight, and there were no cracks either on back or face. The metal appeared to be much more homogeneous than the others. Preference should be given to the Creusot plate."

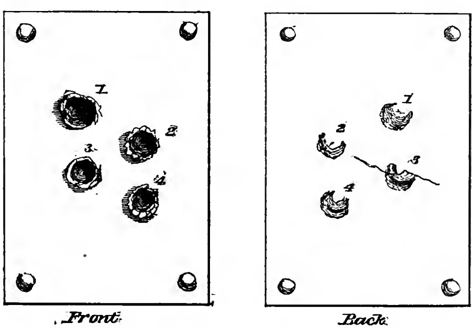
The contract for the deck-plating was given to Creusot, and in November, 1879, several batches of plates of different thicknesses were tested, and as they were all comparatively thin plates the ex-

periments are of great interest in showing the resisting power of thin steel to direct impact. They were unbacked and were fired at with the 3½ inch Krupp gun, the projectile being of steel and weighing 16½ lbs. In no case was the shot broken or appreciably deformed.



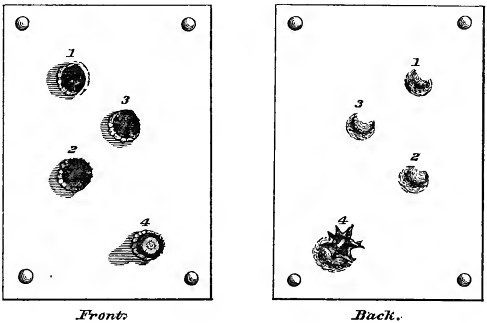
Schneider Steel 1½ inch Plate.

The first plate was a 1½ inch. 1st shot, energy per inch of circumference 5.2 foot-tons. Star-crack on front of plate and slight crack across bulge at rear; no daylight showing through. 2d shot same energy. Hole made in plate about 1½ inch in diameter; star-cracks front and rear. 3d shot, same energy; same effect as No. 1. 4th shot, energy 8.9 foot-tons per inch. Shot clear through the plate; star-cracks formed. Total effects well localized. No cracks interfering.



Schneider Steel 2¼ inch Plate.

The second plate was a $2\frac{1}{4}$ inch. 1st shot made a barely noticeable crack on the bulge at the back. 2d and 4th shots like No. 1, and the 3d shot a more pronounced crack extending beyond the edge of the bulge on both sides. Energy in all cases 8.9 foot-tons per inch.



Schneider Steel $3\frac{1}{2}$ inch Plate.

The third plate was a $3\frac{1}{2}$ inch. 1st shot, energy 12.6 foot-tons per inch. Slight bulge at the back, but no crack. 2d shot, same energy and same effect as No. 1. 3d shot, energy 16.9 foot-tons per inch, same effect as No. 1. 4th shot, energy 21 foot-tons per inch. Plate broken open at the rear and the point of the shot showing through. Shot stuck in the plate. The greatest bulge without breaking on this plate was a little over half an inch.

In May, 1880, a test of a Wilson plate was made, which gave a very excellent result due to a slight modification in the method of manufacture. With this plate, the iron rear face had been stood on end; a mould was applied to the front, and the molten steel was poured in while in this position instead of, as formerly, being poured on the plate while horizontal. The plate was a 9-inch one like those of the Inflexible, except that it was made up of 5 inches of iron and 4 inches of steel. The gun used was a 9-inch, and three shots were planted on the plate. The result was considerably better than that of the test of the Inflexible plate. A trial of a second similar plate under identical conditions gave a still better result, and seemed to guarantee the excellence of this modification in factory work.

Before the close of the spring of 1880 the manufacture of both

compound and steel armor plates had reached a stage of development where they were brought into the closest competition. The firms of Cammel & Co. and Brown & Co., in England, were the foremost builders of compound armor, and Schneider & Co., in France, were the leaders in the manufacture of steel plates. Since the Spezia experiments of 1876 the equipment of the Creusot (Schneider) manufactory had been increased remarkably by the introduction of an eighty-ton steam hammer, with furnaces and cranes of a corresponding size; whilst a constant study of the peculiarities of steel plates had led to a high state of perfection in manufacture. In England the financial support given by the Admiralty and the War Office to the firms of Cammel and Brown had enabled them to rapidly pass the first period of semi-failure and to turn out heavy compound plates as rapidly and with as great a certainty of regularity in resisting power as had been possible a few years before with iron plates.

In July, 1880, an experiment was made at Shoeburyness with a Cammel 18-inch plate; the heaviest yet manufactured, made up of 13 inches of iron with a five-inch hard steel face. This was tested with the 38-ton 12½-inch gun, using the service charge and Palliser projectile. The head of the shot stuck in the plate without penetrating to the iron. The body of the projectile was broken to pieces, and the steel plate was flaked off quite deeply for a radius of about 8 inches around the point of impact. Two cracks were started extending to the edges of the plate, although neither went completely through.

During the summer of this year the French Government, desiring to provide armor of the most perfect type for their new ironclads, inaugurated a series of competitive tests, at the naval firing-ground of Gavres, between Cammel and Schneider plates of from 16 to 22 inches in thickness. Full reports of these tests have never been made public, but the Government decided in favor of compound plates, mainly on account of the fact, that although they were badly shattered by the 13-inch rifle, yet they covered their targets after the fourth shot, while the Schneider plates were either shattered or pierced at the second. Whilst, however, their decision was in favor of the English system, their report laid great stress upon the possibilities of the development of steel, and in order to aid the Creusot works as far as possible a contract was made with Schneider to furnish the side armor of the ironclad Terrible.

In April, 1881, both Cammel and Schneider plates were tested at

Gavres for reception, and these tests furnish an interesting episode in the development of the rival dispositions. The Cammel plate was for the turret of the Requin and was $17\frac{3}{4}$ inches thick, made up of 13 inches of iron and $4\frac{3}{4}$ inches of steel. The Schneider plate was a side plate of the Terrible, tapering from $19\frac{1}{2}$ inches at the top to 16 inches at the bottom. In both cases the French 32-centimeter ($12\frac{1}{2}$-inch) gun was used, with Palliser chilled shot of 759 lbs., and a charge of powder of 150 lbs., except the third shot on the Schneider plate, which was fired with a charge of 161 lbs. The following is a summary of the effects of the three shots on each plate:

First Shot.

Cammel plate.—Energy per inch of shot, 274 foot-tons; penetration 8 inches.

Schneider plate.—Energy per inch of shot, 270 foot-tons; penetration $9\frac{1}{2}$ inches.

On the Cammel plate two cracks developed, one going entirely through the plate from the shot-hole to the upper edge; the other of no importance. On the Schneider plate three fine cracks developed, tending to separate the plate into three pieces.

Second Shot.

Cammel plate.—Energy per inch of shot, 274 foot-tons; penetration $9\frac{3}{4}$ inches.

Schneider plate.—Energy per inch of shot, 270 foot-tons; penetration $6\frac{3}{8}$ inches.

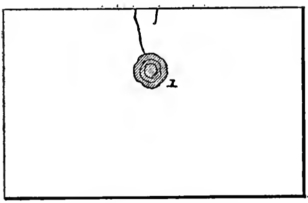
On the Cammel plate the through-crack of the first shot was extended to the bottom of the plate. Eight new surface-cracks developed. On the Schneider plate no new cracks developed; the old cracks spread through the plate.

Third Shot.

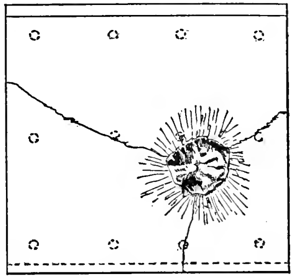
Cammel plate.—Energy per inch of shot, 274 foot-tons; penetration $15\frac{9}{10}$ inches.

Schneider plate.—Energy per inch of shot, 297 foot-tons; penetration 3 inches.

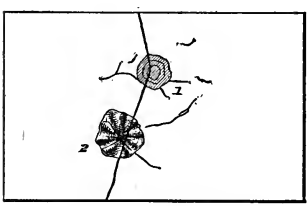
On the Cammel plate the cracks were developed into splits, separating the plate into three unconnected parts, held by their bolts to the backing. On the Schneider plate two new cracks of no import-



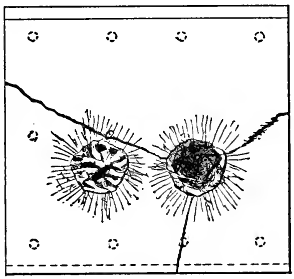
Cammel Plate 1st Shot.



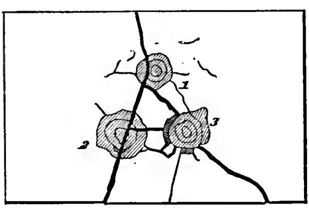
Schneider Plate 1st. Shot.



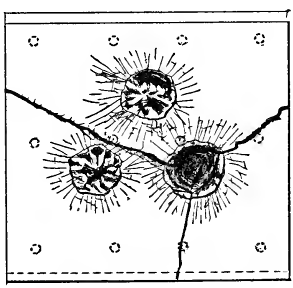
Cammel Plate 2nd. Shot.



Schneider Plate 2nd Shot.



Cammel Plate 3d. Shot.

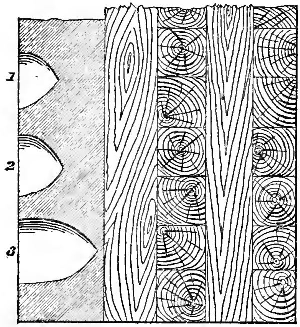


Schneider Plate 3rd. Shot.

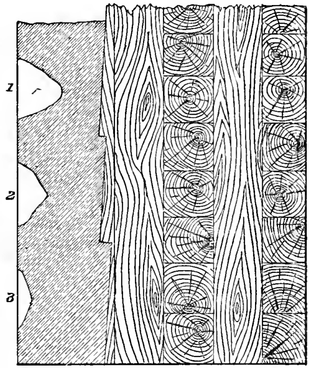
18 inch Plates at Gavres.

ance were developed. The other cracks were spread, but the plate was not completely split.

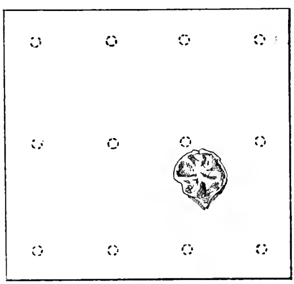
In December, 1881, another Schneider plate from a second lot intended for the side-armor of the Terrible was tested under the same conditions, giving even better results than the previous one. The same gun, charge, and projectile were used as in the previous test, and the plate was of the same dimensions.



Cammel Plate (Section) Requin.



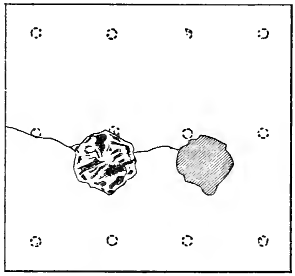
Schneider. Plate (Section) Terrible.



Schneider Plate 1st. Shot.

First Shot.

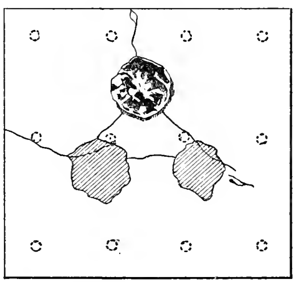
Energy per inch of shot, 274 foot-tons; penetration 4 inches. No cracks visible.



Schneider Plate 2nd. Shot.

Second Shot.

Energy per inch of shot, 274 foot-tons; penetration 8.9 inches. Crack opened from the left edge, through the shot-hole, and to shot No. 1. Greatest width of crack, 0.2 inch.



Schneider Plate 3rd. Shot.

Third Shot.

Energy per inch of shot, 300 foot-tons; penetration $8\frac{3}{4}$ inches. Crack opened from the top of the plate to No. 3, extending clear through. Two fine cracks connecting No. 3 with 1 and 2

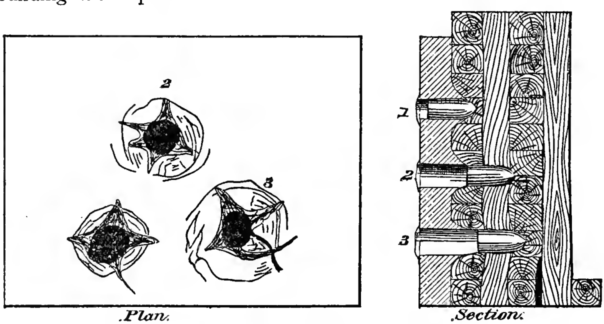
The plate, when dismounted from the target, remained whole. No bolts were broken and the backing was uninjured.

In the latter part of 1880, a test was made at Portsmouth of a compound plate made under a modification of the Ellis patent by Brown

& Co. The modification in manufacture consisted in rolling a hard steel-face plate, which was then placed in the mould at a certain distance from the iron one, and then, both plates being brought to a welding heat, molten mild steel was poured between them, after which the whole mass was rolled to the desired dimensions. In this instance the original thickness of iron was 14 inches, of the steel face plate 2 inches, and of soft steel 5 inches, or altogether a thickness of 21 inches. The finished thickness of the plate was 10½ inches, having been rolled down one-half. The plate was tested with three shots from the 9 inch gun, using Palliser projectiles. The penetration was 5 inches for the first two shots, and 5½ inches for the third. The first and third shots produced only insignificant cracks, the second one opening a crack through the steel. The success of this method of construction led the Admiralty to order similar plates for the armor of the Conqueror.

From these detailed experiments it is made evident that the manufacture of thoroughly excellent plates of both steel and compound armor was assured in 1881. From this time a very sharp rivalry sprang up between the two systems, one of which was thoroughly English and the other just as exclusively French. As a rule, successes on either side have been alone reported, so that it is a matter of more than ordinary interest to describe two decided and public failures, the one occurring with compound and the other with steel armor.

In June, 1881, Cammel & Co. delivered at Kummersdorf, Prussia, an 8 inch test plate, of a lot intended for the two Chinese ironclads building at that place.



Cammel Plate at Kummersdorf.

This plate was tested with the Krupp 17 centimeter ($6\frac{3}{4}$ inch) gun, using Gruson chilled projectiles.

1st Shot. Energy per inch of shot 91 foot-tons. Point of shot through the plate and 6 inches into the backing.

2d Shot. Energy per inch of shot, 92 foot-tons. Point of shot through the plate and 17 inches into the backing.

3d Shot. Energy per inch of shot 92 foot-tons. The whole projectile completely through the plate.

The plate was condemned. A few months afterward, however, a similar test-plate was tried with the following results, the same gun and charge being used.

1st Shot. Energy per inch of shot 90 foot-tons; considerable bulging at the back, but no cracks. Penetration not given.

2d Shot. Same energy, bulge as before with a through-crack across the bulge; point of shot not visible.

3d Shot. Same energy; bulge as before with a through-crack on the bulge; point of shot distinctly visible. Appearance on the front of the plate of a tendency of the steel to separate from the iron.

In 1882 the Russians invited the firms of Cammel and Schneider to submit test-plates for a competitive trial, and in November a very interesting test took place at Ochta, near St. Petersburg. The plates were 8 feet by 7 feet by 12 inches thick, the compound one being made up of 8 inches of iron with 4 inches steel face, Wilson's system. The gun used was the 11 inch Russian rifle, firing chilled projectiles at a range of 120 yards. The plates were bolted to 12 inch backing with $\frac{3}{4}$ inch iron skin; the Schneider plate being held by 12 bolts, whilst the Cammel had but 4.

First Shot.

Schneider plate. Energy per inch of shot 252 foot-tons. Penetration 13 inches.

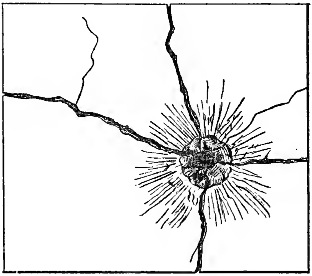
Cammel plate. Energy per inch of shot 252 foot-tons. Penetration 5 inches.

The Schneider plate was broken into five pieces, which, however, were held well together on the target by the bolts.

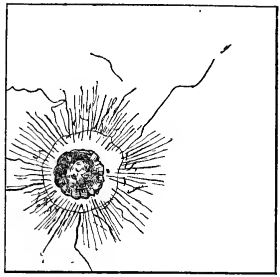
The Cammel plate had a number of face-cracks started, which were not of a serious nature. Three of its four bolts were broken.

Second Shot.

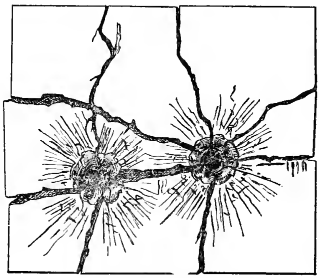
Schneider plate. Energy per inch of shot 151 foot-tons. Penetration 16 inches.



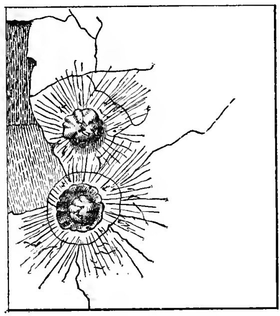
Schneider, 1st Shot.



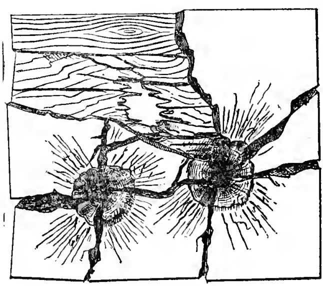
Cammel, 1st Shot.



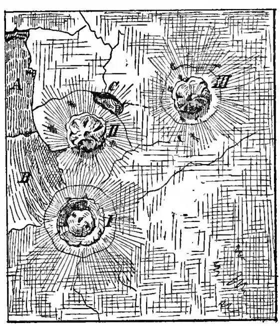
Schneider, 2nd Shot.



Cammel, 2nd Shot



Schneider, 3d Shot.



Cammel Plate, (3rd Shot.)

Cammel plate. Energy per inch of shot 151 foot-tons. Penetration not given.

The Schneider plate was broken into nine separate pieces. Previous cracks opened out, and three new ones formed, gaping from 2 to 3 inches. The Cammel plate fell from its target, the remaining bolt having been broken. The upper left-hand corner was broken completely off, and a piece of the steel face below it, varying from 1½ to 3 inches in thickness, was scaled off. Several new face cracks formed.

Third Shot.

Schneider plate. Energy per inch of shot 151 foot-tons. Complete penetration.

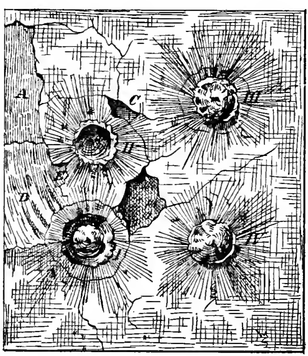
Cammel plate. Energy per inch of shot 151 foot-tons. Penetration 3½ inches.

Nearly half of the Schneider plate was knocked off the target. One piece weighing about a ton was found 13 feet behind it. The projectile was found 740 yards behind the target uninjured.

The Cammel plate having been rebolted to its target after the second shot, it was found that a few new face-cracks had been started and a small piece of the steel face was knocked out.

Fourth Shot.

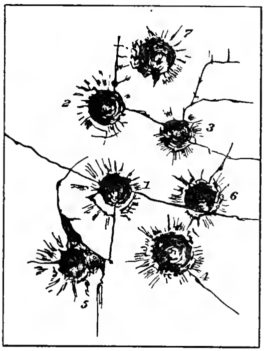
On the Cammel plate alone, with the same energy as before. Penetration not given. Three new face-cracks started and a piece of the steel face knocked out.



Cammel Plate of Ochta,
4th Shot.

This test showed a marked superiority of the Cammel plate over the Schneider, but it cannot be considered, as many have thought, to have established the superiority of the compound disposition over the steel. It is very certain that the Schneider plate was a poor one, as shown by the great penetration and breaking up of the plate at the first shot. The thorough excellence of the compound disposition was, however, determined; for, as will be shown, this plate had been equalled before in power of resistance.

In June, 1882, a test was made of a compound taper-plate, intended for the water-line belt of the Russian cruising ironclad Vladimir Monomack. This plate had a 2-inch steel face; the total thickness being 6 inches at the top and 4 inches at the bottom. The 7-inch rifle was used in the test, firing chilled projectiles with an energy sufficient to pierce $5\frac{1}{2}$ inches of wrought iron (35 foot-tons per inch). Three shots were fired, all of which bulged and cracked the back of the plate. The penetration averaged about $3\frac{1}{2}$ inches; face-cracks being formed after each shot. It was found that water would pass through cracks made by the last shot.



Collingwood Plate.

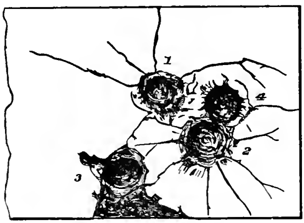
An 11-inch test plate intended for the armor of the Collingwood showed a remarkable endurance. This was a Wilson plate made up of the usual proportions of $\frac{1}{3}$ steel and $\frac{2}{3}$ iron. It was first tested with a 9-inch rifle and Palliser projectiles. Three shots were fired, with the following results:

No. 1.—Penetration $4\frac{1}{2}$ inches. Five small surface-cracks.
No. 2.—Penetration $5\frac{1}{4}$ inches. Four new small surface-cracks.
No. 3.—Penetration $4\frac{9}{10}$ inches. One new surface-crack.

The plate was bulged at the back by each shot, the height of the bulges being from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. The 9-inch having proved itself no match for the plate, a 10-inch rifle was tried and four more shots were fired, with the following effects:

No. 4.—Penetration $4\frac{1}{2}$ inches. Two new cracks developed.
No. 5.—Penetration $4\frac{1}{2}$ inches. Four new cracks developed.
No. 6.—Penetration $4\frac{1}{2}$ inches. Two very superficial cracks.
No. 7.—Penetration $4\frac{1}{2}$ inches. Two very superficial cracks.

None of the cracks made by the 10 inch went beyond the steel face. The bulges at the back were the same as before.



Ellis 11 inch Plate.

Shortly after the test of the Collingwood plate an 11-inch plate, made by Brown & Co. on the Ellis system, was tried at Shoeburyness, being made up of 7 inches of iron and 4 inches of steel. Four shots were fired at it from a 9-inch rifle, the first three being Palliser chilled and the fourth a Cammel steel shot, with the following effects. (The plate was supported against heavy backing, but was not bolted to it.)

1st Shot. Energy per inch of shot 364 foot-tons. Penetration $5\frac{1}{2}$ inches. Seven radial cracks were started of which only one was important, reaching to the top of the plate and being $6\frac{1}{2}$ inches deep. The bulge at the back of the plate was 1 inch high and showed three hair cracks.

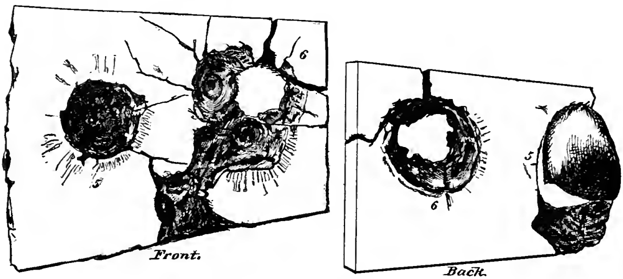
2d Shot. Energy per inch of shot 322 foot-tons. Penetration $6\frac{1}{2}$ inches. Five fine cracks started, but none of them important. Bulge at the back, one inch high, without cracks.

3d Shot. Energy per inch of shot 400 foot-tons. Penetration 6.9 inches. The cracks previously made were slightly opened and one

new crack was formed. A piece of the steel face was broken out. Bulge at the back one inch high with one small crack.

4th Shot. Energy per inch of shot 344 foot-tons. Penetration 6.7 inches. This shot struck close to the second one. Several new and fine cracks were started. Bulge at the back ½ an inch, with a few hair cracks. The shot broke up like the chilled ones.

As a large part of this plate was still uninjured, it was determined a few months afterward to try the effects of the 38-ton 12½-inch gun on it. Two shots were fired with the following effects, both projectiles being made of Cammel steel.



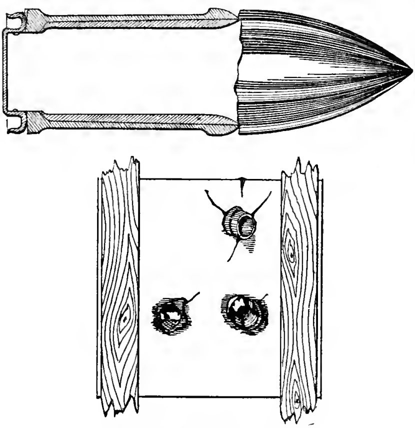
Ellis 11 inch Plate.

5th Shot. Energy per inch of shot 765 foot-tons. Plate broken clear through, a disc of the size of the shot being pushed into the backing. No new cracks were formed. The shot did not get through the backing, but broke up badly.

6th Shot. Energy per inch of shot 757 foot-tons. This shot struck nearly in the mark of No. 4. The corner of the plate was knocked completely off, the whole plate was broken up and the backing was pierced. A large section of the steel face was knocked out, making an odd-looking crater. The shot broke up badly.

A very interesting experiment was carried on in June, 1882, with a new system of projectiles designed by Sir William Palliser. The shot was made with the head independent of the body. The head itself, which was an ogival, struck with a long radius (two diameters), had a series of triangular blades cast with it, which were to assist the shot in getting through by their wedging and shearing action. The steel body was made up in a variety of ways, all tending, however, to

develop a certain action, which was to aid by its energy in pushing the head through the plate whilst it was torn off and left behind so as to save the drag through the metal. Three shots were fired from the 13 pdr., using these projectiles against a 4-inch Cammel compound plate, with the following results:



Palliser Patent Shot and Target.

First Shot. The body of the shell pierced the plate and went into the butt, the exterior envelope was torn off and broken, the interior one stuck in the hole. Plate developed a through-crack at its upper edge, which only became noticeable after the other shots were fired. Three radial cracks developed around the shot-hole.

Second Shot. Clear through the plate, except the exterior jacket, which broke up.

Third Shot. Clear through the plate, projectile broke up.

An ordinary Palliser chilled shot fired at this plate with a slightly greater energy broke to pieces without harming the plate beyond bulging the back.

A further test was made in the spring of 1883 with this system, using the 64 pdr. calibre, and the report of the result of the experiment was quite unfavorable; stating that more damage was done by the ordinary Palliser chilled shot than by the modified one.

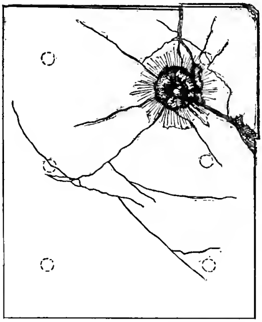
In November, 1882, the 100-ton gun was brought into requisition to settle the vexed question of compound versus steel armor. The Italian Government sent invitations to the three great armor manufacturing firms of Cammel, Brown and Schneider to submit test plates of armor for competitive trial at Spezia, in order to determine the system to be used on the gun-tower of the Lepanto, one of the two largest war vessels in the world. Each firm was to submit a plate made in accordance with its own ideas, the plates to be 10 feet 10 inches long by 8 feet 7 inches wide by 18.9 inches thick. The three plates were made according to the three different methods adopted by the firms. The Cammel plate was made up of about 13 inches of iron with a 6-inch steel face, the latter containing $\frac{59}{100}$ of one per cent. of carbon; the face was applied by Wilson's method, and the plate was rolled down from about 30 inches to the finished thickness. The Brown plate had about the same proportion of steel and iron, the former containing $\frac{7}{10}$ of one per cent. of carbon. It was made up by Ellis's method, of running molten steel between a rolled steel face plate and the iron body. The Schneider plate was of solid steel, containing $\frac{45}{100}$ of one per cent. of carbon, the face for a depth of about 6 inches having been tempered in oil. The two English manufacturers had decided to use but 6 bolts in fastening their plates, whilst Schneider used 20. The plates were bolted to an oak backing of 20 inches, and each plate was enclosed in a frame of iron armor as an additional support.

1st Round.

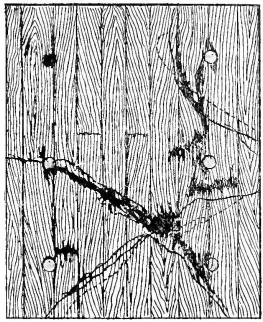
Shot 2000 lbs. (Gregorini chilled iron). Charge 328½ lbs. Fossano powder. Striking energy per inch of shot 371.7 foot tons. Struck the Cammel plate. Penetration 6.9 inches. The lower right-hand corner was broken fairly away from the plate, being held by a single bolt. A number of hair cracks were started covering the face of the plate. The whole plate was set back three inches at the part struck. In the rear one plate-bolt was broken and several smaller backing and frame bolts.

2d Round.

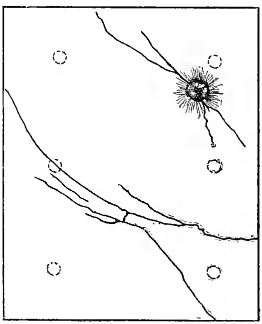
Shot 2000 lbs. (Gregorini chilled iron). Charge 328½ lbs. Fossano powder. Striking energy per inch of shot 379.8 foot tons. Struck the Schneider plate. Penetration 8¼ inches. No cracks or signs of weakness shown, no armor bolts broken, no injury to backing, the plate was not set back.



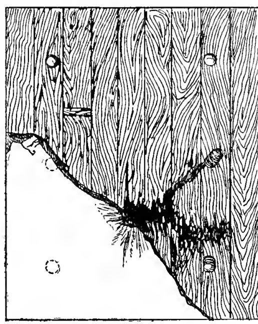
Cammel Plate. (1st Shot)



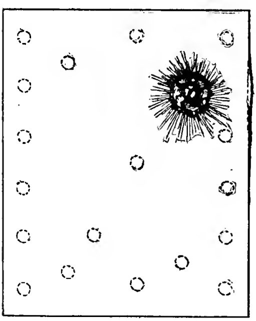
Cammel Plate, (2nd Shot)



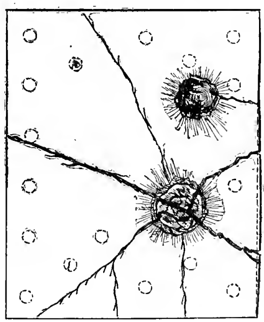
Brown Plate, (1st Shot)



Brown Plate, (2nd Shot)



Schneider Plate. (1st Shot)



Schneider Plate. (2nd Shot)

3d Round.

Shot 2000 lbs. (Gregorini chilled iron). Charge 328½ lbs. Fossano powder. Striking energy per inch of shot 373.8 foot tons. Struck the Brown plate. Penetration 3 inches. The plate showed one decided crack across its face and several hair cracks. The whole plate was set back about two inches, and there appeared to be a slight concavity in the vicinity of the shot-hole, while the Schneider plate had showed a slight bulging at that point. No armor bolts broken.

4th Round.

Shot 2000 lbs. (Gregorini chilled iron). Charge 478.3 lbs. Fossano powder. Striking energy per inch of shot 605 foot tons. Struck the Schneider plate. Penetration 9¼ inches. The plate split vertically and continued to crackle for several minutes, cracks forming and opening until the main one was 0.9 inch wide at the bottom and 0.7 inch just above the point of impact. Deep hair cracks were opened, one of them extending through the plate. No armor bolts broken.

5th Round.

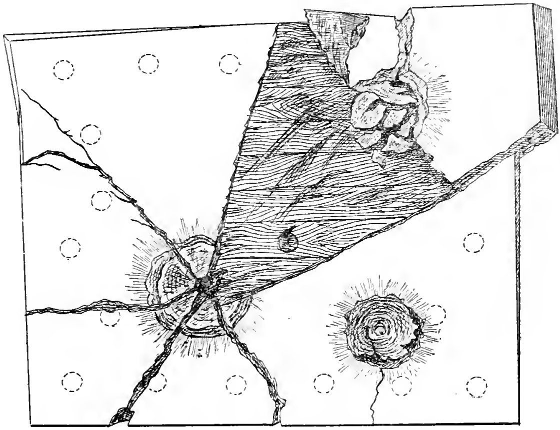
Shot 2000 lbs. (Gregorini chilled iron). Charge 478 lbs. Fossano powder. Striking energy per inch of shot 612 foot tons. Struck the Brown plate. Penetration about 8 inches. The plate was split into six main pieces, all of which except one were thrown from the target, the latter being held by two bolts. The wood backing in the centre was broken and torn. At the back two beams were badly broken and forced back. All the armor bolts except two were snapped or drawn.

6th Round.

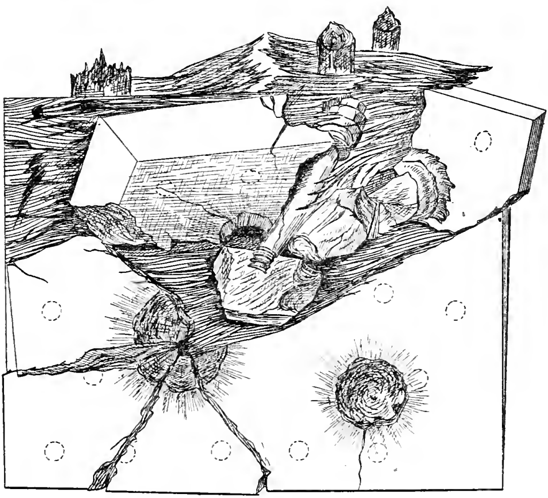
Shot 2000 lbs. (Gregorini chilled iron). Charge 478 lbs. Fossano powder. Striking energy per inch of shot 613 foot tons. Struck the Cammel plate. Penetration about 8 inches. Plate smashed and knocked completely off the target. All the bolts either drawn or snapped. Backing badly split and torn. One beam in rear broken. The plate was bulged at the rear opposite the point of impact.

7th Round.

Shot 2078 lbs. (*Terre Noire steel*). Charge 478 lbs. Fossano powder. Striking energy per inch of shot 615 foot tons. Struck the Schneider plate. Penetration 12½ inches. A large portion of the centre of the plate was broken out and the upper right quarter was



Schneider Plate (3rd Shot.)



Schneider Plate (4th. Shot.)

displaced. The shot was much set up and the extreme point was broken off. The original length of the shot was 44½ inches, which after impact was reduced by crushing to 28 inches. The backing was somewhat split and torn. At the back seven beams were broken and displaced. One armor bolt was partially driven out.

8th Round.

Shot 2124 lbs. (Gregorini cast and tempered steel). Charge 478 lbs. Fossano powder. Striking energy per inch of shot 607.7 foot tons. Struck the Schneider plate, passing through it and the backing, being picked up broken to pieces behind the target. The piece of plate struck was completely smashed, the largest of the remnants hanging on by a bolt. Some of the fragments were driven through the target to a distance of 6 feet to the rear.

The following extracts from the official report of the Italian Commission are interesting in the conclusions reached, and furnish much valuable information with regard to the state of development of heavy plate manufacture.

"From an accurate examination of the cracks and the fractured sections, it was observed that in the compound plates the steel, and also the iron, showed rather a coarse grain; distinct strata of the metal imperfectly welded were noticed as well as cavities and traces of scoria. It was also noticed that the thickness of the steel stratum was not uniform, varying from 6¼ to 4¾ inches. It was also noticed that in the weld of the two metals the iron presented a spongy appearance as if it were of inferior quality. In general, the anomalies indicated above were more apparent in the Brown plate than in the other, although there was more regularity in the thickness of the steel.

"It should be noted with regard to the cracks, that while in the compound plates they were both radial and concentric, in the Schneider plates they were exclusively radial. Moreover, in the compound plates the cracks were in continuous and well-defined lines, showing signs of the marked effect of the molecular separation of the metal, while on the contrary in the Schneider plate, on account of the peculiar fibre of its steel, the cracks were serrated throughout the thickness of the metal. In the Schneider plate a very fine grain was observed, uniform and compact, and showing much greater molecular tenacity. The committee thinks these differences in the characters of the metal in the two systems of armor may be principally

attributed to the difference of the force of compression to which the plates are subjected in manufacture. . . . . A very great difference was observed in the quality of the metal of the armor-bolts. In fact, the rupture in the English bolts showed a grain approaching the characteristics of cast metal, as the fact proved that with one exception, none of the English bolts that were broken presented any indications of torsion. Precisely the opposite was noted in the French bolts, none of which were broken, and only a few twisted, but without a sign of fracture, as if the metal were soft and ductile. . . . .

"In view of the results of the two shots against each of the experimental plates, the Commission is able to conclude: 1st. That the Schneider plate, though it may have permitted a greater penetration, proved superior to the compound plates and better adapted to protect a ship's side. 2d. To give absolute judgment on the degree of superiority of the Schneider plate, the committee is of the opinion, that it would have been necessary for the plates to have been secured to the backing in exactly the same way, as well in number as in the quality of the bolts.

"Another conclusion that can be drawn from these experiments, from the compound plates as well as the Schneider, is, that lineal measurement, which is still used in comparing penetration in them with that of iron of equal thickness, can no longer serve as a criterion of the value of their resistance, because the plates of both systems present a much greater resistance to penetration than they do to the racking effects or to general destruction, so that in practice the plate which permits the greater penetration, but which has greater tenacity, will stand best. On the other hand a projectile which has less energy per inch of circumference, whilst it possesses greater total energy, will be more powerful. In other words, hard metal plates are split to pieces by a lighter blow than would be necessary to penetrate them, which shows that this force, instead of being employed principally to obtain penetration, might be utilized to give a greater racking blow, which would be the result of flattening the head of the projectile, and greater results would follow, since the relatively useless work, that makes the point seek an opening by separating the fibres of metal, would go towards increasing the blow and would augment the general damage of the plate.

"This consideration is especially important for compound plates, since the experiments show that, while through the hardness of their steel, they offer a resistance more than sufficient and somewhat greater

than that of the Schneider, yet on account of their lack of tenacity, they present less resistance than the latter to a powerful racking blow.

"It may be inferred from the foregoing that it no longer answers in practice to value the resistance of plates similar to those experimental ones, by using the energy per inch of circumference of the projectile, and the best unit of measure for such valuation is the total energy. It is equally seen that the best projectile to be used against modern armor-plates, is not that already having the greatest energy in respect to its calibre, but that which possesses an absolutely greater total force of impact.

"The Commission does not possess sufficient data to estimate how much farther the manufacture of compound armor can be improved, but it seems that important advantages would be gained if the following suggestions were accepted:

(*a*) Greater force in lamination.

(*b*) Uniformity in the thickness of the steel.

(*c*) A system of fastening which will prevent the broken pieces of plate from falling from the backing.

(*d*) That a quality of metal should be used for the bolts that would attain a high degree of ductility, in order to eliminate almost every danger of breaking.

"The Committee being able to deduce rules from the results of the two rounds upon each of the three plates, is of the opinion that these trials should not be inferior to those which the Schneider plate proved its ability to withstand. . . . . The Committee, therefore, is of the opinion that for the compound plates intended for the Italia, the following test trials should be ordered:

"1. Plates selected for the firing trial should be secured to a wooden backing of about 80 centimeters (30 inches) in any way most agreeable to the manufacturer.

"2. The plate shall receive a round in the centre with a Gregorini chilled shot, fired from the 100-ton M. L. R. to realize a force equal to that required to penetrate iron of 25 per cent. greater thickness. The energy of the projectile to be determined by the Muggiano formula.

"3. The shot not to go through the plate, and no piece of the armor to be detached from the backing on account of any cracks that may be produced.

"And finally, to be sure that no plates ordered shall prove inferior to those that have satisfactorily sustained the trials stated in the pre-

ceding paragraphs, the Committee is of the opinion that samples of every plate, including that to be experimented with, should be submitted to mechanical tests in the same way and by the same rules observed on the occasion of the manufacture and test of the plates for the Duilio and Dandolo."

This grand armor test, like the one of 1876, created a great excitement amongst artillerists. It must, however, be viewed in an entirely different light from the earlier one. The trial of 1876 resulted in the overthrow of a system which had reached the absolute end of its development. That of 1882 only marked a *stage* in the new development. By it no question of the absolute superiority in the development of a system was or could be settled; nor was it the intention or the hope of the Italian Government, that any absolute decision could be reached beyond the one of the proper *test* to which such heavy armor should be submitted. Much fault has been found with the meagreness of the report of the Committee, especially in that its conclusions were devoted almost entirely to the detail of the best form of test to be given to plates submitted for trial; also complaint of unfairness has been made in that, whilst the Schneider plate showed superior resisting power at the trial, the plates to be used on the Italia are to be Cammel and Brown compound ones. This fault-finding arises wholly from a misconception of the circumstances under which the experiments took place. The contracts for the armor of the Italia had already been awarded long before the experiments took place, and without previous competitive test. This trial was intended solely to establish a method of testing plates of the different deliveries for acceptance; there having been a great uncertainty as to what was the best arrangement of firing that should do equal justice to the government and the manufacturers. Schneider was invited to submit a plate in order that advantage might be taken with future ships, of any superiority that his target should develop. Regarded in this, its true light, the report becomes one of great importance; the method of test prescribed by it has been adopted by the British Government, in place of the former method of firing three shots on the apices of an equilateral triangle, and the severity of the new test will undoubtedly lead to a great and rapid improvement in the resisting power of both steel and compound plates.

On account of this same misunderstanding with regard to the object of the test, a very violent attack was made by the minority of the Italian Assembly, upon the action taken by the Minister of Marine in

awarding the contracts for the Italia's armor to Cammel and Brown, extending to a general attack upon the whole policy of the naval administration. In his response to these attacks, Admiral Acton, the Minister of Marine, made a most excellent defence, and his argument presents the advantages of compound armor in the strongest light possible. It should not be assumed, however, as has been done by many who have studied this report, that the Admiral condemns steel armor or even considers its possibilities of development inferior to those of steel. He very properly warns his countrymen against being carried away by the great apparent superiority of steel over compound plates, as shown by the Spezia experiments, quoting the Ochta ones in which compound armor was more decidedly victorious over steel, in support of his argument. Just in the same way people should not be carried away by the Ochta experiments, since the test of the second delivery of "Terrible" plates at Gavres, shows conclusively that most excellent results can be obtained with steel.

In reviewing the whole subject, it is seen that the commencement of the development of both steel and compound armor dates as far back as 1858. After the first tests, which naturally were unsatisfactory, the development was left to private energy alone, unsupported by the governments on account of the immediate necessity for armor and the great cost of steel. In passing the 12-inch limit of wrought iron, the embarrassments of manufacture and of weight of armor became superior to the benefits derived from absolute thickness of plate. The test of 1876, at Spezia, showed the world that steel had at last arrived at the point where it could successfully assert its supremacy. The firm of Cammel & Co. had labored almost unaided to overcome the intractability of steel, choosing as their line of development a method of compounding steel and iron. Whitworth, in England, was also trying to solve the problem by taming the steel itself. It has been shown that in the first English tests, Whitworth's steel plates were much superior to Cammel's compound ones, but the apparent enmity existing between the government authorities and Whitworth led to the aid of the former being given to Cammel. Development followed with remarkably rapid strides; without doubt more rapid than it would have been had Whitworth been the favored individual, and this not so much on account of the superiority of the system as for personal reasons. Whilst, however, Schneider received the pecuniary advantages arising from the contracts for the armor of the Duilio and Dandolo, he was handicapped in his development by the necessity of

working on great thicknesses instead of the medium ones. As a general result, compound armor very quickly took the lead in development, but this lead has never been great. At present the rivalry between the two systems is very great. It seems unquestionable that they must approach each other as they approach perfection, and as yet it is impossible to tell whether the true method of approach will be by the compound system doing away with its distinctive features, or the steel system adopting some of those of its opponent.

It must be remembered that the ultimate object of naval armor is to attain the greatest amount of protective power with the least possible weight, and since there is a minimum limit of space to be defended which cannot be reduced, the reduction in weight must be accomplished by a reduction in thickness. Taking first the case of a compound plate, it is evident that the iron back gives a minimum of resisting power; its main object being to hold the hard steel face up to its work. Great surface hardness is readily and safely obtainable, and as yet no absolute conclusions have been reached as to the true proportion which the thickness of the iron should bear to that of the steel. Owing to the great ductility of iron a considerable thickness of steel is necessary, to aid by its greater stiffness and prevent the iron from giving back so much as to distort the steel face and tear it from its connection. If now the greater resisting power of steel can be successfully utilized so that a soft steel back may be made to do the duty imposed upon the iron at present, then the true object of the armor of obtaining the greatest resisting power for a given thickness will be obtained. If this method be adopted, however, the compound plate becomes virtually a steel one, differing solely in method of manufacture.

Turning now to the steel system, it is evident at once that by adopting the metal of greatest resistance throughout, the attempt is made to reach the desired end directly. The element of molecular disturbance enters here, however, as a serious drawback to development. (The effects of molecular disturbance are discussed in the chapter on the Manufacture of Armor.) Up to the present time it has been found absolutely impossible to give to Schneider plates the same amount of surface hardness as is possible with the compound ones, and as has already been shown, this feature is a prime necessity in true development in order that the projectile shall be forced to work destructively upon itself. Whitworth has accomplished the feat, although under a modified form. It would seem then that, pro-

vided this surface hardening be possible, the true line of development lies in the direction of the all-steel plate. To say that it is impossible, or that it is impossible to give to steel the qualities demanded in the backing of a steel face, would be a most dangerous assertion in the face of the great progress shown by comparing the Schneider plates of 1876 with those of 1882; the behavior of the Schneider plate compared with that of the Marrel iron plate in the Tordenskjold experiment and the Terrible test-plates with the compound Requin ones. Nor has the last word been heard yet from the Whitworth, Terre Noire and Basic methods of manufacture.

In closing this chapter, the attention is specially called to the importance which "Armor Fastenings" has come to assume in the disposition of armor. The system of bolting has been completely revolutionized, in that bolts are now not permitted to go through the plates. Whilst the size of bolt, the play of the shank, the male screw-thread, and the rubber washer of the old system are retained, the number of fastenings must be increased, and the question arises, is this to be a permanent feature or not? Schneider wins many victories by numerous bolts, but here it would seem that although the compound plates are at a disadvantage at present from the limited number used, true development points to reduction rather than additions of fastenings, since they are an element of weakness in reality in destroying the homogeneity of the structure and adding to the weight and cost.

VI.

Inclined Armor. Grüson Chilled Armor.

The first step taken in the development of armor, and one which was probably co-existent with its original application to war-vessels, was that of gaining whatever advantages might be due to presenting its surface obliquely to the line of fire of artillery. The proposition submitted by John Stevens to the United States Government in 1813 contained the specification that the vessel was to be protected by inclined armor. It needs no demonstration to prove the existence of advantages, both in the tendency of the resolved energy to glance the shot from the face of the target, and in the increased thickness to be pierced by a projectile striking a plate in any direction not normal to the face; but however great the magnitude may appear in the abstract, the difficulties encountered in applying such dispositions to vessels of war, such as loss of very necessary space, additional weight for the protection of a given area, etc., make it necessary that the absolute value in protective power of the various dispositions should be known, in order that a true balance may be struck between it and the constructional disadvantages.

For convenience of discussion, the various dispositions will be classed under three distinct heads: 1st. What may be termed "Steep inclination," comprehending all those dispositions which seek to gain the advantages of inclination without completely sacrificing the natural uses of the vertical space immediately behind the armor; such as gun-space in the battery, or living-room in other parts of a vessel. The lower limit of this inclination may be assumed at 30° from the horizontal. 2d. "Shield inclination," or those dispositions which make the availability of the space in rear entirely subsidiary to the factor of protection offered by inclination. These dispositions lie between angles of 30° and 5° from the horizontal. 3d. "Deck inclination," or those dispositions which are applied to decks proper which vary from the dead-flat to an extreme crown-angle of 5°.

Steep Inclination.

The only tests of importance of the effects of *spherical* projectiles on steep inclined armor, are those furnished in the Civil War, by the

New Ironsides, the ironclads on the Western rivers and Confederate ironclads. In the case of the New Ironsides, the inclination of the casemate armor of about 60° from the horizontal, without doubt contributed somewhat to her invulnerability. In this ship, however, it may be questioned whether the increased immunity from penetration was not too dearly purchased. Her armor was sufficiently strong to thoroughly resist penetration from the guns attacking her even had it been disposed vertically, and such an arrangement would have saved her over 50 tons of dead weight, would have given a clearer space for manœuvring her guns, better ventilation for her battery deck, and an increase of upper deck room. The saving in weight is the main consideration, and it would probably have lightened her draft considerably. The Western river gunboats and the Confederate ironclads realized greater benefits from the inclination, and in their cases constructional advantages had to be sacrificed to the disposition entirely; for in the one case, the necessity of fighting under a plunging fire from high river banks required the greatest reduction of upper deck space possible. Only a certain weight, and that not great, was available for armor, and it had to be distributed in such a manner as to give overhead as well as broadside protection. Whilst a greater weight for armor was permissible on the Confederate vessels Virginia, Atlanta and Tennessee, the weakness of its composition, forced by the lack of proper appliances to make good armor-plates, made it necessary to gain all the advantages that inclination could afford; and in these vessels steep inclination was carried to the extreme point of 30°, beyond which it would have been impracticable to work guns in the confined space behind it. This inclination was sufficient to completely neutralize the 11-inch smoothbore, and to prevent the ingress of 15-inch shot into the battery. Whilst, however, this steep inclination was an excellent check to smoothbore projectiles, the advantages were very much modified when rifled shot were brought to bear upon it.

In June, 1861, a series of experiments was carried on at Shoeburyness against plates inclined at various angles. The first plates tested were ¾ inch, against which shot were fired from the 6 pdr. rifle. It was found that there was no apparent difference in the powers of resistance of the plates when placed at angles of 60°, 45° and 30°, and when placed vertically. A 1½ inch plate was next tried, and after it a 3 inch plate, using the 12 and 40 pdrs. and but very little difference was notable between the vertical and 45° positions.

In January, 1862, a test was made of the comparative resistance of two wrought-iron plates *containing the same amount of iron*, and covering the same vertical area, the thicker plate being placed vertical and the thinner one at 45°. The dimensions of the two plates were 36 inches × 48 inches × 4½ inches and 36 inches × 72 inches × 3¼ inches. The 40 pdr. and 100 pdr. Armstrong rifles were used on both plates. No advantage was recognizable arising from the obliquity.

The Iron Committee, referring to these experiments in their first report, make the following statement: "With the 100 pdr. Armstrong at 200 yards distance the vertical plate was broken, but not penetrated; but the oblique plate was penetrated and the backing destroyed.

"This appears to show that no advantage is gained by placing iron plates at an angle where, by doing so, the plate must be made thinner to compensate for an extended area.

"We by no means assert that a 4½ inch plate will not present a greater resistance when placed obliquely than when placed vertically, especially in the case of spherical shot; but we think that the iron is more usefully disposed in vertical plates of a given thickness, than the same *weight* would be if disposed in thinner plates placed obliquely to protect the same vertical area."

In November, 1862, the committee fired some cast-iron and homogeneous metal shot and shells from the Whitworth 12 pdr. at a 2½ inch iron plate, placed at an angle of 45°. The cast-iron shot were broken up on impact, the pieces deflected, and hardly any injury caused to the plate. The homogeneous metal shells, which were fired without bursting charges, passed through the plate, and were so little distorted that they could be fired a second time from the same gun.

Not long afterwards a valuable series of experiments was carried on with the 9 inch Woolwich rifle firing projectiles of different material and form of head, against 8 inch plates with a Warrior backing, the target being at first vertical and then inclined at angles of 39° and 30° with the horizontal. Sixteen shots were fired at it vertical, all of which pierced the plate completely, three going clear through the target. Of five shots at the 39° position, two penetrated less than three inches, two less than four inches and one penetrated five inches. In these cases, though the heads were ogival, they were struck with a short radius (one diameter). Of fourteen shots at the 30° position,

none penetrated less than three inches, three were less than four inches, four were over seven and less than eight inches, four were a little over eight inches, and three were almost through the target. From an examination of the record there seems to be no way of explaining the slight penetration at 39° compared with that at 30°, unless it be assumed that the shot broke up earlier; it is seen, however, that whilst the inclination had a marked effect in reducing penetration, it was not sufficient at the maximum to make the shot glance without biting well into the plate.

In 1869 Whitworth made some private comparative tests between flat and ogival-headed shot, and found that at 45° and 30° from the horizontal the flat-headed shot would readily pierce a target where an ogival-headed one would be glanced off, but at the extreme angle the latter shot would bite deeply into the armor.

In an official report made by Captain Noble in 1866, the following observations are made with regard to oblique impact:

"Let us suppose, however, that the plate has been set at an angle, or that the gun fires obliquely at an upright plate. The shot has then a tendency to glance off, and continue its motion in a new direction. And we shall have the following well-known proportion, viz.

"The force with which the shot, acting obliquely, will strike, is to that with which it would strike if acting directly, as the sine of the angle of incidence is to unity. It appears from this that the resistance of the plate increases as the value of the angle decreases.

"We have already shown that a 4½-inch unbacked plate when fired at direct, requires a force represented by 28 foot-tons per inch of shot's circumference to ensure penetration. Let us suppose, however, that we place the plate in such a position that it makes an angle of 38° with the ground. We find that the force required to penetrate it in this position amounts to 73.9 foot-tons per inch of shot's circumference. We may expect, therefore, that a less force will not penetrate a 4½-inch unbacked plate at an angle of 38°.

"An experiment of this nature was actually tried by the Armstrong and Whitworth committee. They caused 4½-inch plates to be set up at an angle of 52° with the vertical, and fired at them from 200 yards distance. It appears that the projectiles were solid steel shot of 70 lbs. weight; that they struck with a 'work' of 52.7 foot-tons per inch of shot's circumference, and that they *failed to pass through*, although the plate was cracked and opened at the back."

A few years ago, experiments were carried on at Shoeburyness

with 12-inch plates of wrought iron, inclined at angles of from 60° to 53° from the horizontal, and also with a 10-inch compound plate at angles of from 65° to 63° with the horizontal. From these tests the general law was established, that when wrought-iron armor was beyond the power of the gun (at normal impact) deflection took place at about 60°, but when the plate was below the power of the gun, projectiles would pierce at about 50°. If the power of the gun was much in excess of that of the plate, penetration would be effected at much smaller angles.

On the other hand, steel-faced armor caused the projectile to deflect more readily. When this armor was beyond the power of the gun, the projectile would not bite the plate at a less angle than about 65°, but when the armor was not equal to the gun, penetration took place at this angle.

Experiments carried on at Gavres led to the establishment of a French rule of oblique penetration quite similar to the English one, as follows:

As long as the angle of incidence is not greater than 30° (that is, if the plate is not inclined less than 60° from the horizontal), a projectile of good material will pierce the plate, provided that the normal component of the striking velocity is equal to or greater than the velocity necessary for the projectile to pierce the plate normally. Beyond inclinations of 60° to the horizontal, chilled projectiles striking the plate are broken, and if the individual pieces have not the force to pierce the plate normally, they are glanced off. Beyond the angle of incidence of 44° (46° to the horizontal) which is the point-angle of the ogival shot (radius 1½ diameters) the projectile will not bite the armor, and is glanced off without doing serious damage, unless the normal component of the energy is sufficient to smash a hole through the target, in which case the target is broken through and damage is caused by flying splinters, although the projectile itself is carried off.

This rule requires modification when good steel projectiles are used with an ogival head of two diameters, as was shown in an armor experiment at Meppen in 1882, where an 8-inch wrought-iron plate backed by 10 inches of oak and a 1-inch skin was fired at by a 5¾ inch gun with steel projectiles, the angle of incidence being 35° (55° inclination from the horizontal). Two shots were fired, both of which pierced the target fairly. Both projectiles were broken up (shells), while two similar ones, fired normally, went through without being perceptibly deformed.

From these various tests the following rules for the application of steep inclined armor may be deduced:

If it be a question of furnishing protection against spherical projectiles, or cast-iron ones, an inclination of armor of 60° from the horizontal is of great assistance, but against rifled chilled or steel projectiles it is of no use at all. Beyond a slope of 60° the question of loss of space behind the armor becomes a matter for serious consideration, whilst the certainty of making a rifled projectile glance short of 44° slope (corresponding to the angle of an ogival head of $1\frac{1}{2}$ diameters) is not only not established, but as improvements are made in the materials of projectiles and as striking energy is increased the chances of penetration are made more favorable. Furthermore, it is quite well established that, although the striking energy required to drive a flat-fronted projectile through a plate is quite $\frac{7}{8}$ of that required for an ogival point, the flat-fronted one will bite an armor effectively at an inclination of 30° from the horizontal. Another consideration of great importance in the application of armor to ships is that of weight, and it can be very well illustrated by an example.

Suppose that a weight of 75 tons was all that could be permitted in armor for the protection of one side of a battery deck. This weight applied in vertical armor would allow a space to be covered 50 feet long by 7 feet high with 12-inch plates, which could be pierced by the Woolwich 10-inch rifle at about 800 yards. Let it be attempted to slope this armor at an angle of 45°, in order to gain the protection due to the tendency to deflect and the increased thickness caused by the slope. In the inclination, three factors enter into the limitations: 1st. The same length must be covered. 2d. The same height must be protected. 3d. No more weight can be permitted. The width or height of the plates instead of being 7 feet is now $9\frac{9}{10}$ feet, and to keep the same weight, the thickness of plate is reduced from 12 inches to $8\frac{1}{2}$ inches. The energy per inch of the 10-inch projectile required to pierce the 12-inch plate normally is 135 foot-tons, whilst its actual energy is about 160 tons per inch. The energy required to pierce the $8\frac{1}{2}$-inch plate normally is about 77 foot-tons per inch, whilst the normal component of the 10-inch projectile striking at an angle of 45° is over 80 tons per inch. So nothing is gained whatever.

It is for these reasons that steep inclination is never resorted to in applying armor to ships except in cases where the object to be attained is something connected with the actual construction of the ship, such as corner ports in redoubts, etc.

Shield Inclination.

The first recorded experiments on armor at the inclinations included under this head were made by Colonels Colquhoun and Sandham in 1846, in which they used a $\frac{5}{8}$-inch plate roughly backed, and fired at with 8-inch shells and 32 pdr. solid shot. It was found that both the shell and shot were almost invariably broken up on impact. (Reference has already been made to the discovery made some years later, that in normal fire $\frac{5}{8}$-inch plates would break up 68 pdr. and 32 pdr. projectiles.) When the shot were broken the splinters were deflected. A 32 pdr. shot striking where a former one had hit, with the plate at an angle of 30° with the horizontal, passed through the plate and 4 feet of oak. Another 32 pdr. fired with an increased charge broke up, and some pieces penetrated 3 feet into the oak backing.

In 1862 experiments were carried on at the Washington Navy Yard, using 11-inch spherical solid shot against targets inclined at 15° with the horizontal. The first target was made up of two $\frac{1}{2}$-inch boiler plates bolted together, with 1 inch of rubber and 7 inches of yellow pine as backing. The first shot tore a hole clear through the target 3 feet 8 inches long by $8\frac{3}{4}$ inches wide. Shot itself glanced off at an angle of 9° with the face of the plate. The second shot had about the same effect although it struck a weaker part of the target. A second target was then tested, using two thicknesses of 1-inch plates with $1\frac{3}{4}$ inch rubber and 7 inches of yellow pine; same angle of inclination. The shot broke a hole clear through, 2 feet $8\frac{1}{2}$ inches long by $7\frac{1}{8}$ inches wide, glancing off at an angle of 9°. A third target was next tried, made up of two 1-inch plates with 1 inch rubber and 7 inches of pine backing. Two shots were fired at it with practically the same effect as before, large holes being smashed clear through, while the shot glanced off at an angle somewhat less than the angle of impact. The same target gave about the same result when hit by a 150 pdr. Parrott rifled shot. The angle of inclination was then reduced to 5° with the horizontal, the rubber being removed. The 11-inch shot made an extreme indentation of $2\frac{3}{4}$ inches for a length of 3 feet. The backing and 12-inch timbers in rear were broken.

About the same time a test was made of the armor proposed for the Stevens battery. The target was made of plates varying in thickness from $\frac{5}{8}$ inch to 2 inches, giving a total laminated thickness of $6\frac{3}{4}$ inches, backed by 7 inches of locust, which was strengthened

by iron stringers 6 inches deep (thus corresponding quite closely with the Chalmers disposition which marked a prominent step in the development of armor). Behind the backing was a ½-inch iron skin. The inclination of the target was 27½° from the horizontal. It was hit by two shots from a 10 inch smoothbore and one from a 100 pdr. rifle, the penetrations not extending 2 inches in depth, whilst the backing was uninjured, these effects correspond quite well with those of the 11-inch smoothbore on the casemates of the Confederate ironclads; unfortunately in both cases the guns were not worked at much over one-half of their full power.

During the months of June and July, 1872, a very interesting series of experiments was carried on against targets representing the upper and lower decks of the Thunderer, the angles of incidence corresponding to angular positions of the deck of from 8° to 10°. The upper-deck target consisted of three thicknesses of 1 inch plates covered with 4 inch oak, the deck being supported by iron beams 11 inches deep by ½ inch thick and reinforced by ½-inch angle-irons. The lower-deck target consisted of two thicknesses of 1-inch plates covered with 3½-inch oak plank and supported like the other. The 9-inch and 10-inch rifles were used at 100 yards range, with service charges and shells, some of the 9-inch projectiles being experimental steel ones with flat heads. Seven projectiles struck the upper-deck target, and six hit the lower-deck one: in no case did the projectile itself get through either at 8° or 10°, but one 10-inch shell which exploded on contact not only made a hole through, but drove a mass of dangerous splinters below. The lower plate of the lower-deck target was broken to pieces, and beams in both targets were broken, split and twisted; in several cases rivets were driven through. In almost every case cracks were made completely through sufficient to cause bad leaks. It was noticeable that only one shell exploded on impact, and judging from its effects, had others done the same, much splintering inside would have been caused. It was considered that the upper-deck target was sufficiently strong to resist 9-inch and 10 inch Woolwich projectiles at an angle of 10°, although for greater security a substitution was recommended of one 1-inch and one 2-inch plate in place of the three 1-inch ones.

About the same time experiments were carried on at Gavres against targets representing the decks of the Friedland, Redoubtable, and what was called an English deck. The Friedland target consisted of ½-inch steel plates covered with 4½ inches of oak, and supported by heavy

iron T beams. The Redoubtable deck consisted of 2-inch steel plates covered and supported like the other. The English target consisted of two 1-inch steel plates covered and supported as before. The guns used were the 27 centimeter ($10\frac{3}{4}$ inch) and 22 centimeter ($8\frac{3}{4}$ inch) French rifles, firing both shot and shell.

The results as summarised in the official report were as follows: For inclinations between 5° and 9° the ogival $10\frac{3}{4}$-inch solid shot ricocheted from the Redoubtable target without dangerous effects. Beyond these inclinations, for the Redoubtable deck, and beyond 5° for the Friedland and English decks, the $10\frac{3}{4}$ inch solid shot either pierced or broke and splintered the targets badly.

Ogival and cylindrical projectiles produced equivalent effects.

Exploding shells were extremely destructive.

Cast-iron shells broke up before accomplishing any marked destructive effect.

The $8\frac{3}{4}$ inch projectile was considered powerless against the decks of the Redoubtable type below angles of 25°.

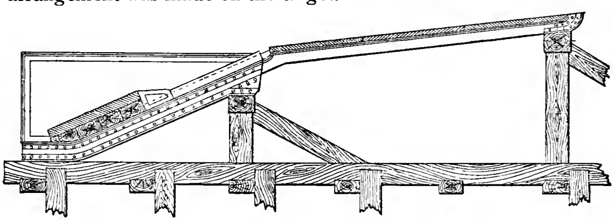
In June and July, 1881, a test was made at Spezia of deck-plates manufactured by different firms and inclined at angles of 5°, 10° and 15°. The gun used was a 25 centimeter ($9\frac{3}{4}$ inch) Italian gun, with service charges and common cast-iron shells. The plates submitted were: one Creusot steel plate of 3 inches, one Cammel steel plate of $2\frac{3}{4}$ inches, and one Saint Chamond iron plate of 3 inches. At 5° inclination the plates were slightly dished, without cracking; the shells ricocheted, breaking up in one case and remaining entire in two others. At 10° the dishing of the plates was increased to an average of about 2 inches and were all cracked; the projectiles broke up. At 15° all the plates were pierced, but the projectiles did not get through; all the shells were smashed to pieces.

In the spring of 1882, a number of 2-inch steel and iron plates were tested in England at an angle of 10°, using the 9-inch and 10-inch Woolwich guns with service charges and common shells, as well as Palliser chilled projectiles. All the Palliser shot from both guns broke up on impact, breaking holes through the plates and sending splinters below, although no pieces of projectiles went through. The majority of the shells exploded just after impact, with a great increase of destructive effect over that caused when no explosion took place. The whole deck structure represented by the target was broken down by a few shots.

The most complete tests that have as yet been made upon targets

at the "shield inclination," were carried on in March, 1883, at Copenhagen, by the Danish Government. The target represented a section of a deck-shield proposed for a new ironclad, and was made up of plates at two different angles. The plates on the upper half were 2 inch and would be horizontal in the actual deck structure, but owing to the great difficulty of hitting them in the experiments they were placed at an angle of 7°. The lower part of the target was covered with 4-inch plates at an angle of 24°. The plates attached to the target were from the three great rival armor manufacturers; Schneider having submitted steel plates, Cammel, compound ones, and Marrel iron ones. The thin plates on the upper part of the target had no backing proper, thus representing the English deck system, whilst the thicker plates on the lower section were backed in the French deck style with 2 inch plank. The deck proper *under* the unbacked plates was made up of two ¼-inch steel plates riveted together, whilst underneath the backed plates it was a single ⅜-inch steel plate. The armor plates were fastened to the deck by 2-inch bolts with rubber washers under the nuts.

The section of the target sloped at 24° represented the chord connecting the dead-flat of the deck proper with a point at the side of the ship well below the water-line, and as in the vessel herself the compartment made by this slope was to be filled with cork, the same arrangement was made on the target.



Section of Copenhagen Target.

The dead-flat deck, represented by the 7° section, was prolonged with a ¼-inch steel plate to a second and vertical plate ½ inch thick, which represented the ceiling of the ship's side. The triangular box thus formed over the 4-inch armor plates was filled with cork, some sections of which had been specially prepared so as to be fire-proof. The 7° section of the target consisted of three strakes of plates, which were secured directly to the deck plates proper, and these

deck plates were differently arranged under each strake. Under the first one the deck consisted of two ¼-inch steel plates riveted together. Under the second strake it was of single ⅜-inch steel plates, with double-lapped joints. Under the third strake it was of single ⅜-inch steel plates, plain butt-jointed, with seam-straps.

Two guns were used against this target, a 9-inch Armstrong muzzle-loader, and a 15 centimeter (5¾-inch) Krupp breech-loader of the latest 35 calibre type. A point of great importance with regard to the projectile energy of these guns, which made the experiments of the highest value, was, that whilst the total striking energy of the 9-inch projectile was about one-half greater than that of the 6-inch, the energy per inch of circumference was very nearly the same in both, as follows :

Krupp.	Energy per inch	123 foot-tons.	Total energy	5760 foot-tons.
Armstrong.	" "	118 "	"	16403 "

The programme of experiments detailed three separate sets of tests to be carried on, on three days, as follows :

1st Day. Test of the 2-inch plates forming the upper part of the target, with both guns, in order to test the relative qualities of the competing plates and the best disposition of deck.

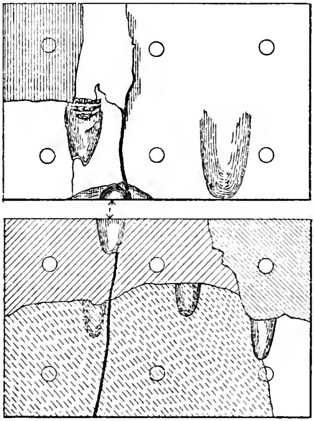
2d Day. Test of the lower target section. The first part of the test would be to determine the effect of the cork filling upon the direction of the projectile and upon its piercing power. For this, the 6-inch Krupp was used, firing at the upper half of the section in order to get the greatest thickness of cork possible. The second part of the test was to determine the effect on the cork of exploding a shell in it, as well as to test its non-combustibility. The 9-inch Armstrong was used for this part of the test on the lower section of the cork filling, in order to get the highest shell charge and the greatest amount of cork over the point of explosion.

3d Day. The cork filling was removed entirely from the plates, and a direct test of the competing plates was made, using both guns with armor projectiles, having ogival, flat and dished heads.

None of the shots from either gun produced any serious effects on the 2-inch plates inclined at 7°. The Schneider and Cammel plates were very slightly cracked, and all showed the tracks of the projectiles in glancing, but in no case was any damage done to the deck underneath the plates.

Note :—No reports are available with regard to the behavior of the cork filling under fire.

The results of the competitive tests of the 4-inch plates at 24° are as follows:



Schneider Plates.

Schneider Plates.

Shot No. 20 (Krupp 6-inch steel shot). Through the cork filling; struck on the joint between the plates, breaking a small piece from the lower edge of the upper plate, and probably starting a crack (a. a. a. a.) across both plates.

Shot No. 21 (Armstong 9-inch shell). Through the cork filling, exploding and opening the before-mentioned crack clear across and through both plates.

Shot No. 26 (Armstrong 9-inch shot). Hit the upper plate, scoring it deeply.

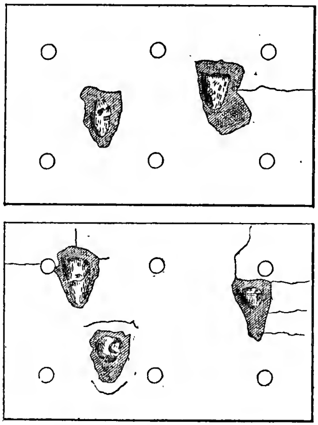
Shot No. 31 (Krupp 6-inch steel shot). Struck the upper plate, splitting the upper left-hand corner and turning the inner edges up at right angles.

Shot No. 33 (Krupp 6-inch steel shot). Hit the lower plate, knocking its upper right-hand corner off (a. d. b.), and starting a crack across the plate.

Shot No. 36 (Krupp 6-inch steel shot). Hit the lower plate, knocking its upper section off the target (a. d. e. f.).

Shot No. 40 (Krupp 6-inch steel shot with dished head). Hit the lower plate, knocking the greater part of the remainder off the target.

Summary. One-quarter of the upper plate and nearly the whole of the lower plate knocked off the target. *No shots through; deck plates* underneath the armor uninjured. Upper plate hit by two 6-inch and two 9-inch shots. Lower plate hit by three 6-inch shots.


Cammel Plates.

Cammel Plates.

Shot No. 22 (9-inch Armstrong shell). Through the cork filling, and exploding without injury to the plate.

Shot No. 24 (6-inch Krupp steel shot). Through the cork filling; struck the lower plate without other damage than starting a few fine cracks.

Shot No. 27 (9-inch Armstrong shot). Hit the top plate and went clear through the plate and deck. Hair cracks started.

Shot No. 32 (9-inch Armstrong shot). Intended for the Schneider plate, but struck the Cammel upper one, going clear through the plate and deck.

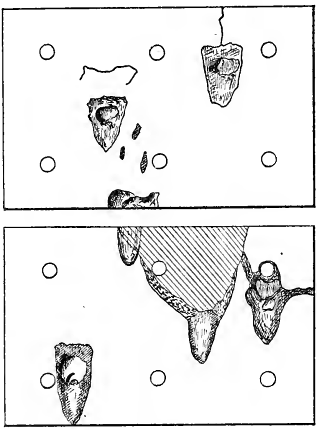
Shot No. 30 (6-inch Krupp steel shot). Hit the upper plate and broke up, part of it going clear through the plate and deck.

Shot No. 34 (6-inch Krupp steel shot). Hit the lower plate and

broke up, part of it going clear through the plate and deck. Cracks started.

Shot No. 37 (6-inch Krupp steel shot). Hit the lower plate and broke up, part of the shot sticking in the hole and part through plate and deck.

Summary. No part of either plate knocked off the target. Two 9-inch shots clear through, with havoc behind the deck. Portions of three 6-inch shots clear through, with havoc behind the deck. Three 9-inch shots and four 6-inch ones struck the plates.



Marrel Plates.

Marrel Plates.

Shot No. 23 (9-inch Armstrong shell). Hit at the joint of the two plates, and split the lower one across.

Shot No. 25 (6-inch Krupp steel shot). Hit close to No. 23, breaking small pieces (a. a. a.) out. Not through.

Shot No. 28 (9-inch Armstrong shot). Hit upper plate, going clear through plate and deck.

Shot No. 29 (6-inch Krupp steel shot). Hit upper plate, going clear through plate and deck.

Shot No. 35 (6-inch Krupp steel shot). Hit the lower plate, going clear through plate and deck.

Shot No. 38 (6-inch Krupp steel shot). Hit the lower plate, making a crack, but not going through.

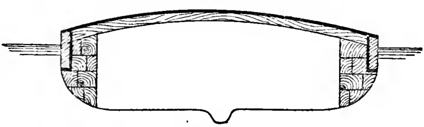
Shot No. 39 (6-inch Krupp steel shot, with dished head). Hit the lower plate, and cut out a large piece through plate and deck. Shot itself not through.

Summary. A large piece of the lower plate cut out. One 9-inch shot clear through, with havoc behind the deck. Two 6-inch shots clear through, with havoc behind the deck. Two 9-inch and five 6-inch projectiles struck the plates.

Judgment was rendered by the Commission in favor of the Schneider target, which, although presenting scarcely any definite power at the end of the test, had successfully defended the space behind throughout the trial. In the results the test resembled very closely the Spezia trial of 1876, in which, as here, the Schneider plate was knocked entirely off the target, but kept the shot out; whilst the Cammel plate stayed on the target, but let the shot through. A great cry has been raised in English papers with regard to the Copenhagen experiments, but certainly without reason. These targets are to protect the machinery of the ship, the most vital of all her parts. A single shot coming through is very liable to disable the engine or boilers, and thus sacrifice the whole vessel. Of what use, then, to contend that *another* shot on the Schneider plate would have gone clear through? Sufficient that in a fight one vessel had resisted the first shot, whilst the other had been pierced. Again, great weight is given to the fact that the Schneider target was laid bare by knocking the plates off; and, in truth, it is a serious matter—fully as vital in one case as in another. Therefore, English critics, before dwelling too much on this point, should remember that at the Ochta experiments the Cammel plate was knocked clear off the target at the second shot. It is true that in that case the fault was in the bolting, while at Copenhagen the fault was in the plate; but the backing was laid bare all the same, and the commander of a ship that sees his side cleared of armor will scarcely be comforted in the heat of action by the thought that the fault was in the bolts and not in the plates. Defence of the vital parts of the ship is the object aimed at, and a sure defence for two or three shots is far preferable to a partial defence for a dozen. Sea actions are in these days short, for the gun is supported by the ram and the torpedo, so that it is of all things necessary to carry engines, steering-gear and artillery safely through the first shock of combat.

In reviewing these various tests it may be safely concluded that 2-inch steel plates, *well supported against flexure*, will give good resistance at angles up to 9°, and possibly 10°; iron plates of that thickness are not safe much over 6°; 4-inch steel or compound plates are scarcely safe above from 15° to 20°, although for a time a certain dependence can be placed in them against guns as high as 6-inch calibre for angles as great as 25°, beyond which shield armor becomes practically useless, as the same weight required for thorough defence may be more effectively disposed vertically, except, as a matter of course, certain structural advantages are to be realized which are not immediately connected with the defensive power of the armor. In all cases the armor must be stiffly backed and held up against flexure. This point has been repeatedly and thoroughly shown by the action of Hotchkiss and Nordenfeldt projectiles on targets representing the bows of torpedo-boats. These shots, striking at angles of 10° against the thin flexible plates, show plainly the action of the plate in giving back under the blow; and before the local reaction of the plate can be brought into play the point of the shot is enabled to bite and slip through.

With regard to the practical application of the "shield protection," its growth appears to have been gradual, commencing with deck curves given to vessels in order to obtain certain structural advantages, and developing into a distinct disposition of armor defence

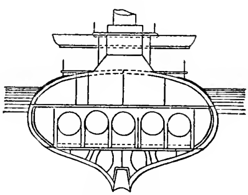


Naubuc

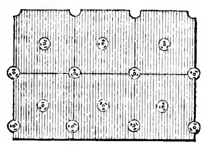
mainly applied in what are known as unarmored vessels. It seems that about the first application was in the United States light-draught monitors in 1863, and the Eads armored vessels Kickapoo and Chickasaw, where the upper deck was worked with a strong curve both athwartships and fore and aft. The angle of the deck at the side of the ship on the midship section was fully 10°, making thus a spring of main beam more than double that of the ordinary deck beam. By this means of curving the deck the height of side armor was kept down, whilst the vertical space underneath required for machinery was preserved. It was intended to secure the advantages

of deflecting the projectiles; but it is very doubtful if any good object would have been attained. The vessels were intended exclusively for river fighting, and it would have been impossible for them to hold a position against a plunging fire from high river banks. The same disposition was made of the upper decks of two light Austrian monitors built about 1863 for service on the Danube.

This system of upper deck curvature was carried to its extreme of development in the designs of an armored ram made by Rear Admiral Ammen, U. S. N., about 1872, the intention being to accomplish a double object by giving both the longitudinal and athwartships sections of the vessel an elliptical shape, thus securing great strength for ramming together with the benefits of deflective power in the above-water sections. A few years afterward this constructional feature appeared in the designs of the English torpedo-ram Polyphemus, a slight modification being introduced by carrying an ordinary flat deck fore and aft over the curved portion, and carrying up a vertical freeboard, thus securing the ordinary form of "entrance"



Polyphemus.

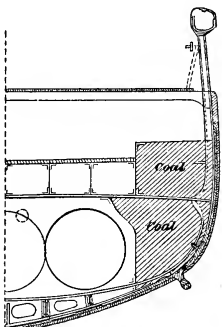


Whitworth Scales.

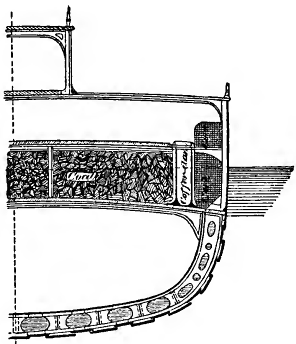
and "run" of the vessel. The extreme angle of inclination (at the side) at the water-line is in this vessel nearly 30°. Her armor also presents a novel feature in being partially composed of square plates of Whitworth compressed steel, reinforced by the system of bolting, the bolts being very hard. This arrangement is a modification of the system submitted for test by Whitworth in 1877, at the time of the test of the first compound plates.

The English corvette Comus, designed about 1875, was the first vessel in which the shield inclination became a special and independent application. Extending over her engines and boilers, and her magazine, which is between the boiler and engine rooms, is an armored shield-deck entirely below the water-line, and having a slightly less curvature than was used in the light-draught monitors.

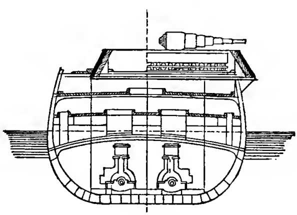
This shield is in no sense a deck, as the berth-deck proper, having the ordinary spring of main-beam, is about three feet above it, *above the water-line*, the space between the two being available for stowing coal or stores. The same arrangement is applied in the Ajax type of ironclads, with minor modifications, such as a slightly increased curvature, and a greater height between decks for coal space.



Comus.



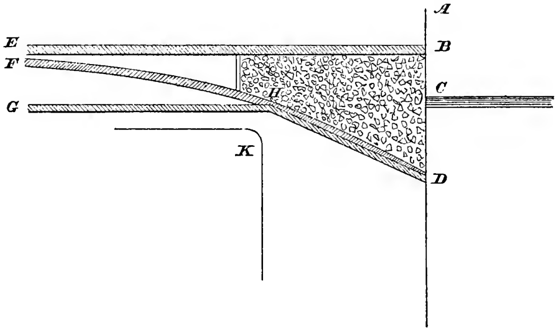
Ajax.



Italia.

In the design of the Italian battle-ships Italia and Lepanto, this curved shield appears developed to the maximum of inclination angle. In this case the shield is carried completely fore and aft, and in order to get over the cylinder-heads of the vertical engines and still keep the housings of the shield at the proper distance below water, the angle of curvature is carried to as great an extreme as is found in the Polyphemus. Here also the crown of the shield is below water, whilst the deck proper overhead is above the load-line, the between space being used for coal and stores.

The shield has now become universally recognized as a necessary attachment to all vessels both armored and unarmored, and the latest modification of it appears in the designs of the English ships of the Leander and Imperieuse types. In this the curved disposition has given way to an angular one, the top of the shield being forced above the water-line by the necessity for covering the tops of boilers and engines, whose height (where great speed and endurance are necessary, combined with a moderate draught of water) brings the top nearly if not quite up to the water-line. In the United States it has been made a matter of much discussion whether this alteration from a curved to an angular disposition is an improvement or a step backward. It seems, however, to be easily susceptible of proof that the angular arrangement presents most decided advantages.



Let *ABCD* represent the side of a vessel, the water-line being at *C*.

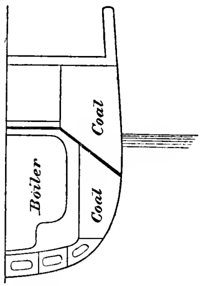
Let *K* represent the upper back corner of a boiler in position, and *H* the nearest point to this corner that a deck or any obstruction can come.

Let *D* represent a point on the ship's side four feet below the water-line, where it is necessary that the housing of the shield should come.

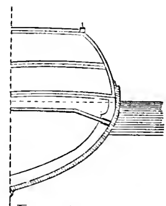
There are two fixed points here that limit the introduction of any deck, be it curved or angular; *D* which limits the range of under-water protection required, and *H* below which nothing can come, as the floor of the ship and height of the boiler establish its position.

Consider the space *HD* to be cut by the section of a curved deck and also by a chord section. Then (since a straight line is the

shortest distance between two points) for a given length and thickness of shield, the chord or flat arrangement will be the lighter; or, what is of greater importance, where a certain allowance of weight is made for the shield, the chord disposition may be made thicker.



Leander



Imperieuse.

With regard to the effect of angular inclination, it will be noticed that: 1st. The mean angle of the curved section is the same as the constant angle of the chord. 2d. At the point D the angle with the horizontal which the chord makes is *less* than that which the curve makes, therefore it will deflect projectiles better. Now this point D, which is the lowest one attainable in practice, may be easily laid bare either by the roll of the ship or by the hollow of a wave, and the only additional protection offered is that of the skin and frame of the vessel; therefore the greatest deflective power obtainable is necessary at this point, and this greatest power is given by the chord disposition. At the point H the angle of the chord with the horizontal is greater than that of the curve, but at this point a horizontal thickness of from seven to ten feet of coal or other substance has been interposed, which effectually neutralizes any difference in angular inclination.

In point of fact, the difference between the chord and the curved disposition between these two points is not noticeable to the eye, and can scarcely be detected by the edge of a ruler on the draft of the athwartship section of a 4000 ton ship made on a one-eighth scale. It is only noticeable in the calculations of weight and the greater work required in curving and fitting the plates and beams.

The great advantage of the chord disposition, however, appears in

the part beyond the point H to the middle line of the vessel. The dead-flat deck connecting the two side chords shows here a very marked decrease of area as well as inclination angle. It is here that the great benefit is derived, for not only can the saving in weight between the two sections be utilized, but the dead-flat may itself be reduced in thickness as a compensation for its small angle from the horizontal. It has been shown heretofore that a thickness of armor for the shield of less than four inches can scarcely be depended upon at a greater angle than 20°. The average angle necessary for this shield is from 22° to 28°. Where a two-inch deck curved with a single radius is put in, the same weight would allow, with the chord disposition, 4-inch plates on the side chords and 1½-inch on the dead-flat.

The point has been made that a curved deck greatly strengthens the ship in ramming as well as in general stiffness. As a matter of fact, the great weight required only permits the application of a shield covering the boiler and engine compartments. In so far, therefore, as ramming is concerned it has no effect at all. As for general strength, the shield, like the armor of an ironclad, can only be regarded as a necessary evil. Ships always have been and always will be built to possess full strength without counting the shield, which is invariably an addition and not a substitution. Such being the case, the question of strength only enters in so far as the deck holding itself up and efficiently performing the work required of it is concerned.

Passed Assistant Engineer N. B. Clark, of the United States Navy, has devoted a great deal of time to the development of the curved system of shield deflection, making a new departure in the disposition by applying it to armored turrets. These turrets are curved above and below a middle line, making a structure not unlike closed clam-shells. The edge angle is from 14° to about 17°. Experiments will soon be carried on with a target representing one of these turret sections, with a view to ascertaining the comparative resisting powers of this turret and an ordinary cylindrical turret *of the same weight*, a second limitation in this case being the requirement that both turrets shall be capable of carrying and manœuvring the same guns. The thickness of armor applied by Mr. Clark is 4 inches, while the armor of the corresponding cylindrical turret is 12 and 14 inches, both being provided with backing.

Deck Inclination.

Deck inclination is simply the extreme of shield inclination, with all the advantages acquired by a reduction of the angle below 5°. It has been seen that 2-inch plates are quite secure as protection at and below 5° provided they are well backed up. Although the natural spring of an armored deck would probably never exceed an extreme of 3°, it would seem necessary to add to this an angle of at least 4° to compensate for the rolling of a ship, this allowance being even below that of easy rolling in an ordinary seaway; that is, in providing armored decks for a vessel allowance should be made for an average impact angle of projectiles at ordinary fighting ranges of at least 7°. In so far as elevation of a deck above the water-line is concerned there is not so much difference in respect of the angle of plunging fire, which for the average height of the upper deck batteries of high-sided ships operating on a deck at the water-line would be only 5° at a distance of about 200 feet. Still, for low decks, it would seem necessary to allow an additional strength due to at least 3° plunging fire, making in all, the strength of armor on a deck near the water line necessary for thorough protection, equivalent to that given to shield armor inclined at about 10°. It would naturally seem that, in establishing the necessary thickness of shield armor, the same allowance should be made for plunging fire and rolling, and such would be the case if the shield were presented to projectiles uncovered as is the case with decks. As a rule, however, shields, especially where arranged as a cover for boilers and engines, are themselves covered with coal, stores, cork filling, &c., and the additional resistance thus offered may be taken as about equivalent to the increase of effectiveness of projectile due to the additional angles.

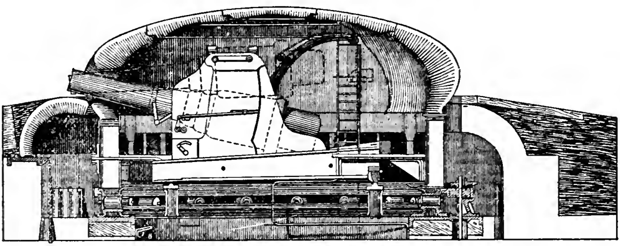
Whilst the very moderate thickness of 2 inches of steel armor on a deck may be considered as giving a fairly good protection against guns carried on an enemy's vessel, the rule cannot be accepted as universal in application. The very low freeboard of the United States monitors demands a greater protection, as a hole punched through the deck endangers the buoyancy of the ship quite as much as a hole through the side of a high-freeboard vessel would. The Catskill in her action with Fort Wagner furnishes a case in point. In this instance, the holes through the deck had to be stopped with shot-plugs while the ship was under fire. All of the monitors before Charleston had difficulty in stopping serious deck-leaks caused by projectiles, although their light deck-armor always kept the shot out

of the ship, and in no case would the wounds have been considered serious in a high-freeboard vessel. Ships intended for river service require an extra thickening of deck armor to compensate for the steep plunging fire of artillery from high banks. Judging from the experiments on the test plates for the Tordenskjold, cited in the previous chapter, it would seem that a thickness of 2½ inches of steel is about the least that can insure protection from field artillery fire. A new and most serious opponent of deck armor is rapidly being developed in the rifled mortar, whose accuracy of fire up to a range of 4000 yards is sufficient to make it an extremely hazardous operation to attempt the bombardment of coast fortifications while in a fixed position, either at anchor or stemming a current. The havoc that would be made by the new missile called the Torpedo shell, dropping through a ship's deck and exploding, may well be imagined when it is known that the projectile of this type for the 8¼-inch Krupp rifled mortar carries an exploding charge of 80 lbs. of powder. In this connection it is perhaps well to correct a very common error with regard to the striking velocity of a mortar projectile falling from a great height. This velocity is not, as many suppose, sufficient to carry the projectile right through the ship so as to punch a hole through her bottom. The velocity at impact is much less than that with which the shot left the gun, for, owing to the rapid increase of resistance of the air as the velocity increases in falling, the point is soon reached where the force of resistance is equal to the acceleration of gravity, and after that the velocity of the projectile is constant. Thus, for every shape and weight of mortar projectile there is a certain maximum falling velocity that cannot be increased. The resultant energy is not considered sufficient to carry a projectile completely through a ship, although in the case of the low-freeboard monitors as they were originally with single bottoms, it would be easily possible for one of the above-mentioned Torpedo shells to explode so near the skin as to tear off whole plates and inevitably sink the ship. This terminal or maximum velocity of falling projectiles may be assumed without great error at about 900 feet per second, in estimating the strength of deck necessary to resist rifled mortar-fire.

Gruson Chilled Armor.

Although chilled cast-iron armor has not and probably never will be applied to vessels of war, the great success that has attended its introduction into coast defence fortifications, and the fact that the

artillery of war vessels will be brought in direct conflict with it, makes it necessary that its qualities and system of application should be understood by naval officers. Herr Gruson, the inventor of this system of defence, has been for the past forty or more years one of the most prominent iron founders of Prussia. As has been before stated, it is a matter of dispute between him and Sir William Palliser as to the credit of the invention of the chilled cast-iron projectile. As soon as the success of the chilled shot had been assured, Herr Gruson was led to the consideration of the question of armor, and he laid down the principle that the main point of the defence did not lie, as was popularly supposed, in *localizing* the work of impact, but in *paralyzing* it. This object would be attained, first, by hardening the surface of the armor so as to cause the energy to react and break up the projectile; second, by curving the surface so that the face of the armor might deflect the shot. Knowing that iron armor could only be hardened by accepting the accompanying fault of the brittleness, he adopted the plan of using a very tenacious and ductile quality of cast iron, which was so cast as to chill the outer surface only for a moderate depth. As cast iron was susceptible of being moulded into any desired shape, he adopted a curved profile for his plate or blocks which, whilst in a certain degree gaining in efficiency through the power of deflection, gained still more by giving to the chilled crystallization a direction such as would put the body of the metal in the



best condition for resistance to impact, and give mutual support to the parts of a plate even when the latter was fractured. Another great advantage was gained by doing away entirely with the necessity of using bolt fastenings. His turrets are built of such a shape (ellipsoidal) as to make all parts mutually supporting, the binding of separate pieces being accomplished by means of zinc solder, precisely as bricks are bound together in a wall by mortar.

Exactly what mixture of ores is used by Gruson is not known, but an examination of the fracture of specimens from his turret plate shows the metal to be of the finest quality of cast iron. The fracture is a clear steely white from the outer surface about one-quarter of the depth of the casting, changing very gradually to a mottle for one-third farther, the remainder being a fine close-grained dark grey iron. There is no line of demarcation whatever between the chill and the soft iron, the one shading off almost imperceptibly into the other. The grain of the iron throughout appears as fine and close as in Whitworth's fluid-compressed steel, and entirely free from flaws, thus exhibiting the great skill with which the casting is made; in fact Herr Gruson claims that he is the only iron founder in the world who can produce such large chills perfectly clear of flaws and surface-cracks.

The first experiment carried on against this chilled armor took place in 1868, on the Prussian firing-ground at Tegel. The target, a casting made especially for the test, consisted of a front plate containing a port, two side plates and two covering or roof plates. It was not believed by the Prussian artillery officers that cast iron, which ordinarily offered such a slight resistance to shots, could give any protection whatever, so the plates were put to an extreme test at once, with the idea that they would crumble at the first blow.

The front plate was hit by 22 shots from different calibred guns, as follows:

Number of Shot.	Kind of Projectile	Striking Energy.
1. 2. 3.	15 centimeters (5.8-inch) steel solid shot . . .	927 foot-tons.
4. 5. 6.	21 " (8.25 ") " " " . . .	3977 "
7.	" " " " chilled hollow shot .	3960 "
8. 9. 10.	" " " " " " " .	4764 "
11.	24 " (9.25 ") steel solid shot . . .	7760 "
12. 13. 14. 15.	" " " " chilled shell	7823 "
16. 17. 18. 19.	21 " (8.25 ") " "	6896 "
20. 21. 22.	" " " " chilled solid shot . .	6871 "

Nos. 1, 2, 3 and 4 had no effect whatever, the points of impact being only marked by slight indents. No. 5 made an indentation of ¼ inch. No. 6 glanced into the port, breaking up and doing considerable damage inside, but with no effect whatever on the plate. No. 7 made an indentation ⅜ inch deep, slight cracks were noticed on the lower side of the plate. No. 8, no noticeable effect. No. 9 started two cracks 7¾ and 9½ inches long. No. 10 broke an oval piece from the plate, not deep enough however to be measured, being

a mere scale. No. 11 started two cracks. No. 12 one crack. No. 13 increased the crack made by No. 9 and forced out a little of the zinc solder from the junction of two plates. No. 14 opened out the cracks made before. Nos. 20 and 21 so weakened the front plate that the casemate was rendered unsafe. No. 22, the upper part of the front plate was dislodged. Of the shots fired, Nos. 5, 11, 14, 16, 17 and 22 struck on a surface of 2½ square feet. This test was considered so satisfactory that orders were given shortly afterward to submit another series of test plates.

The Russian Government appears to have appreciated the possibilities of development of this new armor sooner than the Prussian, for the next test of which a detailed record was made public was carried on at Perm by the Russians in 1871, who, ever since the Tegel experiments of 1868, had been trying independently to manufacture these plates. In this test a large port-plate was used weighing about 50 tons; its thickness varied from 24 inches through the centre to 12 inches at the top and bottom, the metal being chilled for a depth of from 4½ to 3½ inches from the outer surface, then mottled for a farther depth of 6½ inches, the remainder being the soft natural iron. On removing the plate from its mould it was found to have a number of surface cracks on the chilled face, extending in one instance to a depth of 3 inches. In reality then the plate was an unsound one, being so poor that it would have been condemned untried had it been other than a purely experimental one.

Against this target were fired ten 60 pdr. smoothbore projectiles and seventeen 9-inch rifled shot, the striking energy of the latter varying from 10,000 to 16,000 foot-tons. The first seven smoothbore shot made no impression on the plate, not even opening any of the surface-cracks, the maximum penetration being 1⅜ inches. Of the four others that were fired, two struck fairly on deep surface-cracks, breaking out pieces of plate, one of which weighed 72 lbs. and the other 430 lbs.; these pieces were replaced and shored up in position. Of the first six 9-inch shot fired, but one had any serious effect, its penetration being 1¼ inches, causing one of the chill-cracks to open to a width of half an inch. Of the other 9-inch shot fired, the broken pieces of one were thrown back 120 yards from the face of the target; a second shot opened a new and serious crack ⅜ of an inch wide; the fourth one partially destroyed the plate, the chilled part being knocked off from quite a large surface, and the rest of the plate being pierced, although no part of the shot itself got inside. The remaining seven

shots were fired with the extreme energy. The first of these (No. 20) tore off a part of the chill. No. 21 did the same, the head of the shot in this instance remaining fixed in the iron. No. 22 struck on the soft cast iron, tore out a piece and opened new star-cracks. No. 23 increased the damage done by 22. The remaining shots each broke out small pieces. The plate itself succumbed to the guns, but the endurance of the target against the power of the 9-inch gun was remarkable, and the complete smashing of the shot in every case, with the violent reflection of the pieces, gave the best proof possible of the capability of the armor to *paralyze* the projectile, or force its energy to be expended to a very great degree in destroying and glancing, or reflecting the pieces of shot.

The next experiment took place at Tegel in 1873, the target this time being a complete cupola, suitable for mounting a pair of 6-inch Krupp rifles. Before the preliminaries of this test had been arranged an experiment had been made in 1871-72, against a cylindrical wrought-iron plate turret, which had given very satisfactory results, and it was hoped that a parallel series of experiments might be made with the cupola in order to get an exact comparison of the two systems. As the wrought-iron turret was built of unequal thicknesses in its circumference, the cupola was reduced considerably on both sides of the port and in the rear, the thickness of the port plate being made 12¾ inches in order to compare as nearly as possible with the 12-inch thickness of the wrought-iron turret, made up of an 8-inch backed by a 4-inch plate. The cupola was also mounted on the same turn-table that had been used with the turret.

The gun used in both experiments was the 15 centimeter (6-inch) Krupp, at a range of 400 yards, using all the different kinds of projectiles common to that gun. A report of this test, made by Major Küster of the Prussian artillery, contains the following statements:

"In all, the front plate was struck 55 times, 60 per cent. of the shot being chilled ones; the right-side plate was hit 13 times, 9 shots being chilled; the glacis was hit 23 times, 19 shots being chilled, and the roof of the turret was hit twice by 11-inch rifled mortar shells, weighing 440 lbs. each.

"The hits on the front plate from common and long shell made no impression; the chilled shot, however, made flat indents and scaled pieces from the point of impact, generally starting concentric hair cracks, although in some cases they were radial, which afterwards by the racking effect of following hits were lengthened and deepened

and finally broke the plate into several pieces. Several times, also, flat pieces were broke from the outside of the plate ; in no case, however, did a single shot pierce the plate.

"The inefficiency of thin chilled plates was fully shown in the mortar fire received on the covering plates, which completely broke them down at the second fire."

It had been surmised that the blows of shot would crumble the metal into countless pieces, and that the armor would be destroyed by a general dismemberment. The great hardness of the metal, however, effectually counteracted all such action, and its extraordinary resistance to molecular disturbance, combined with the form of double curvature, gives it naturally much more power in increased thicknesses.

The test was considered by the Prussian Artillery Committee to have been a perfect success, but it was thought that farther experiment was necessary, since it appeared that as yet the possibilities of the system had not been exhausted, as improvements in form of profile and increase of thickness might lead to still better results.

Shortly afterward Herr Gruson built a turret at his own expense and offered it to the German Government for test. The turret was intended for a field-work, to hold two 15 centimeter (6-inch) guns. The inside diameter of the cupola was 15¾ feet; the maximum thickness of the port plates was 21⅓ inches, and that of the side and rear plates was 15¾ inches. The total weight of the cupola itself (exclusive of glacis) was 95 tons. The Government accepted Gruson's offer and decided to carry out the test as closely as possible in accordance with the actual circumstances of siege operations. It was estimated that in a thirty days' siege the armor of the cupola would be hit between 1000 and 1500 times, and it was therefore considered absolutely necessary that a quadrant of the experimental cupola should sustain 200 hits from long shell fired from the 15 centimeter gun at a distance of 1200 yards.

If the turret successfully resisted this attack, it should be submitted to another test with the 17 centimeter (6¾-inch) gun. The siege corps was to be provided with heavy siege guns, so that the experiments once commenced, the proper time was to be taken to bring the guns into position as in actual service at a distance of 1200 yards. The preliminary shots were to be followed by a second series with 150 chilled shell. Finally, as it was considered possible that a heavy coast-gun of from 100 to 120 cwt. might be brought into position in the approaches as close as 1200 yards, a third plate was to be fired

at with 20 chilled shot from the 17 centimeter (6¾ inch) gun, and last of all, the covering plates were to receive 5 shots from the 28 centimeter (11 inch) mortar.

The preparations being completed, the first series was commenced May 4th, 1874, in exact correspondence with the programme. The port-plate received 193 direct hits, of which one-third struck on the slightly curved part of the plate above the port and the remainder below the port. They were distributed in about equal proportions all over the plate. Major Küster's report of this test states:

"The result of this first part of the experiment was satisfactory, the turret at the close being as sound as ever. At the 33d shot a piece of metal about 2¼ inches wide had been knocked from the right edge of the right port. At the 70th shot, a fine crack was observed running from the injured spot inwards, but not completely through; this crack did not subsequently alter.

"The effect of oblique hits on the plate was only noticeable from indents of about ¾ of an inch, the point of impact was often undistinguishable, and in cases could only be distinguished by a slight discoloring."

Next, the part of the cupola between the ports was hit by ten 15 centimeter (6-inch) chilled shell having a striking energy of about 1800 foot-tons. These shots had no effect whatever on the target.

Firing then commenced with the 17 centimeter (6¾-inch) gun, with a striking energy of about 3750 foot tons. The sixth shot started a fine crack about 10¼ inches long, which was lengthened at top and bottom by succeeding shots. At the eighth shot, the left corner of the plate was completely carried away, in spite of which, although a serious injury to the upper girding was sustained, the twelve following shots could not bring the plate a single step nearer breaching.

A return was made to the 15 centimeter (6 inch) gun with chilled shot, and 75 shots were fired. The eleventh shot of this series started a crack between the ports, but in spite of this, at the close of the bombardment the plate was in no manner breached. This plate had received in all:

No. of Hits.	Kind of Projectile.		Striking Energy.
193	15 centimeter	(5.8 inch) long shell.	1550 foot tons.
20	17 "	(6.75 inch) chilled shot.	3750 foot tons.
75	15 "	(5.8 inch) chilled shot.	1800 foot tons.

or 288 shots with a total striking energy of 508,150 foot-tons.

Major Küster reports on this result, "that the plate could without doubt have resisted a much greater number of shots. Farther, as this plate has offered a surprising resistance to 17 centimeter armor-piercing shot, and afterwards withstood a great number of 15 centimeter chilled shot, it appears that the front plate not only fulfilled all the requirements of the programme, but showed itself much superior to the expectations formed of it, and therefore well worthy both in shape and power of resistance to serve as a model for farther construction of this type."

The weaker side plates were almost as perfectly successful. First, the right side plate was hit 65 times with chilled 15 centimeter shots (striking energy 1800 foot-tons), which, although they made cracks running crosswise and completely through the plate, did not succeed in loosening a single piece. The left side plate which was chilled harder than the right was also hit 64 times, giving results precisely similar to those against the other side. A farther bombardment of the right side plate with 70 chilled shot (15 centimeter) ended by making a breach.

The covering plates broke down as badly under the mortar fire as they had done in the previous test, so that the committee recommended the substitution of wrought-iron plates for this part of the cupola.

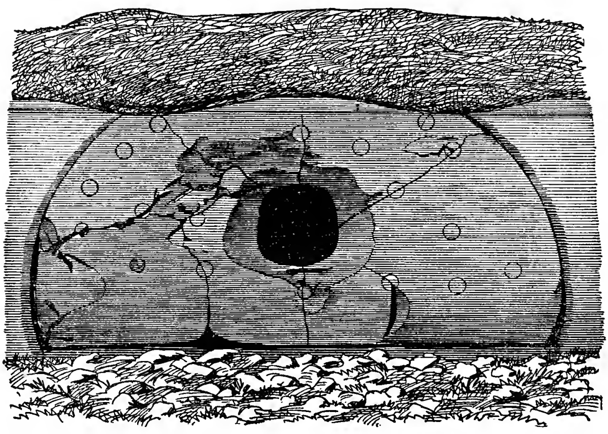
As a direct result of the first experiments made in 1868 the Prussian War Office had given Gruson an order for the construction of a large battery or fort of chilled cast iron for the defence of the mouth of the Weser, built on a shoal called the "Langlutjensand," and rules were laid down for the test of the plates previous to reception. The conditions of the test were that a port-plate should be fairly hit close to the port by two chilled shot fired from a 28-centimeter (11 inch) Krupp rifle, with the service charge, at a range of 760 yards, without disabling the plate and without making such serious cracks as would endanger the life of the plate. This programme was entirely different from the ones previously made, as the service which the plates would be called upon to endure was of a different nature. In the case of inland defences, the turrets or forts would be submitted to a great number of shots from guns of comparatively light power, whilst coast defences would have to resist a few shots from the heaviest guns.

The fabrication of the plates was completed in 1873, and the trial port-plate was put up in position. Its maximum thickness was 33

inches, the average weight being 27 tons per square yard. The result of the test surpassed all expectations. The entire effect of the first shot, with a striking energy of 14,432 foot-tons, consisted in starting a fine hair crack, thereby showing not only the great power of paralyzing energy, but also an extraordinary resistance to molecular disturbance. The effect of the second shot, which struck almost in the same spot as the first, was to start two cracks one-tenth of an inch wide, of which but one was visible at the back of the plate.

The plate having thus fulfilled the requirements of the contract a great desire was manifested to try a third shot in the same place, the effect of this additional blow being to cause the starting of a fine crack from the point of impact to the edge of the plate and to open one of the other cracks somewhat wider.

These remarkable results determined the government to test a second port-plate to failure, the same gun and charge to be used. This plate was precisely similar to the other. The two first shots



had no effect whatever; the third started a crack (No. I) which was visible on the interior of the plate. The fourth continued this crack down the lower part of the plate (No. II), thus splitting it in two. The fifth started another crack (No. III); the sixth and seventh had no effect whatever; the eighth started another crack (No. IV); the ninth and tenth had no effect whatever.

Six months after this test it was determined to again try to breach the same plate, and nine more shots from the same gun were fired, which, although they gave to the exterior a very much battered appearance and opened a few more cracks, could not effect a breach. No single armor-plate had ever before been subjected to such a test, and in no case where armor had been submitted to equal striking energies had the plates offered such thorough protection after ten shots as this had after nineteen. A striking peculiarity is noticeable in this plate, in which the cracks were so distributed as in cases to separate the plate into distinct blocks, but in no case were these blocks driven in. The shape of the exterior face having determined the direction of the granulation of the chill, the cracks all tended to a common axis passing through the centre of figure. The rear surface of the distinct blocks was thus smaller than the front one, giving the block a very slight wedge shape. This, with the great weight of the superincumbent mass, held the whole body together.

A test had been prescribed for the covering plates of this fort. In setting up the test-plate it was so arranged that its front half could only be hit at an angle of about 5° at a distance of 2100 yards. By giving a slope of about 15° to this forward half, a striking angle of 20° was obtained, so that the shot fired with the reduced charge corresponding to a range of 2100 yards would have a striking energy normal to the plate of 1886 foot-tons. Five shots in all were fired at it, none of which breached the plate, although they all started through-cracks.

In December, 1882, a very interesting experiment was made with a plate which had been condemned on account of surface-cracks made in casting. The maximum thickness of the plate was in this case only $17\frac{3}{4}$ inches. The flaws on the surface consisted of one chill-crack $17\frac{3}{4}$ inches long by $\frac{8}{100}$ of an inch wide; a second chill-crack $\frac{8}{100}$ of an inch wide and deep; and an indent caused by a defect in the mould, $\frac{4}{100}$ inch deep and $\frac{8}{100}$ inch wide. The gun used was a Krupp 15 centimeter, with steel projectiles having a striking energy of 1200 foot-tons. Shot No. 1 struck 9° from the normal, making an indent one inch deep; no cracks; shot broke up. Shot No. 2 hit near the flaw, with the same effect as the other. Shot Nos. 3, 4, and 5, same effect. These shots seemed to prove that chill-cracks had no effect in weakening the plate, provided that they did not go through to the soft iron. Shots 6 and 7, no effect. No. 8 started a light hair-crack 6 inches long. Five more shots were fired, making two more hair-

cracks, but not disintegrating the plate at all. The plate thus thoroughly withstood a total striking energy of 16,000 foot-tons. Nine of these shots struck within a rectangle of 24 inches by 15 inches, with a total energy of 11,261 foot-tons.

There is no published account of any experiment made in salvo firing, and it seems odd that no test of the kind should be made, especially on the light cupolas built for inland defence, as they would be much more liable to attacks of salvo firing than coast-forts, and in these cases molecular disturbance might be set up. The record of the experiments cited, however, shows a wonderful power of resistance for cast iron when properly treated, and the question naturally arises: If by means of the chilled surface such a high power of resistance can be attained, is it not fair to look to a corresponding development in compound and steel armor, where, starting with better *natural* qualities for a backing or inside surface, a very hard outer surface may be obtained either by tempering or by the manufacture of hard-surface plates, to be welded on? In Whitworth's fluid compressed steel a great advance already has been made in the quality of plates for armor. It would seem that either through a development of this system, or a combination of fluid compression with some other mechanical device, armor could be kept where it appears to be at present—in advance of artillery power.

The drawback to the applicability of Gruson armor to vessels of war is the great weight, made necessary for a turret sufficient to cover the large guns used. In the form of flat plates, such as would be used for side armor, the whole advantage of the chill is lost, for the crystallization is in a wrong direction, the grain being non-supporting. This fault is manifested very plainly in the chilled projectile, whose point may be carried through many inches of iron or compound armor without deformation, whilst a light blow with a sledge-hammer on the side of the point would knock it off completely. Gruson has designed turrets for small gunboats, intended to shield 6-inch guns, but it is doubtful if he himself would advocate the turret for guns of a higher calibre, as the great weight would call for most serious sacrifices in the other qualities of a vessel.

From the experiments carried on in Germany it has been found that the thickness to give thorough resistance varies quite closely with the fourth root of the striking energy, and the following formula has been adopted for ascertaining the maximum thickness of a port-plate:

$$d = 0.12 \sqrt[4]{m.t.},$$

m. t. being the striking energy in metre-tons and *d* the thickness in metres. For side plates the coefficient is 0.11, and for glacis plates 0.08.

By referring to the Spezia trials of 1876 it will be noticed that two of the targets fired at were provided with chilled-iron plates. A serious error was, however, committed in their disposition, as they were placed behind, instead of in front of, the wrought iron, thus in all probability tending to the same effect as was produced afterwards in the tests of compound armor, where a shot that produced but a slight effect against the face of the plate pierced completely when fired against the back. In any event, however, the faulty crystallization of the block rendered it too weak to withstand a blow from the 100-ton gun, although the resistance offered by the hard metal to the first impact might have so far reacted on the projectile as to keep it from getting through the target.

It will be readily seen what great advantages are realized in the application of this chilled metal to inland fortifications. The material and the manufacture are both comparatively cheap. Masonry is avoided almost entirely, a condition that cannot obtain where wrought-iron plates are used for armor. Sections of the most complicated forms of double curvature can be cast without difficulty, whilst compound, iron, and steel plates must be limited in shape to single curvature. As weight is a matter of secondary importance in fortifications, the thickness of the blocks can be carried as high as desirable without great embarrassment either to the designer or the manufacturer. A matter of the greatest importance to Americans is the fact that it is an easier matter for manufacturers to *learn* to make chilled cast plates than to develop either wrought iron or steel. The cost of the plant necessary for the heavy castings is less than would otherwise be the case. As has been seen from the quoted tests, plates containing chill-cracks and other imperfections still may be considered as offering good defence, so that a lower standard of excellence may be permitted in the first attempts of manufacturers. Finally, for a given expenditure of money a much more extended defence may be realized than with other systems of armor. That these advantages are beyond the region of speculation needs no better proof than the action of Germany, Russia, Holland, Italy, Austria, and Belgium—all of which nations are actively engaged in the construction of this type of defence for their frontiers.

VII.

Armor Manufacture. Laws of Penetration.

However carefully and systematically the effects of projectiles on armor may have been studied by the light of firing-ground work, the knowledge gained will be but crude without the attainment of a certain degree of familiarity with the constitution of the metal of the plates, the phenomena attending their manufacture, and the methods employed in bringing about desired results. Something more is required than a knowledge of the simple definitions of the terms smelting, puddling, tempering, annealing, welding, wire-drawing, &c.; and no true estimate can be made of the value of the developments that have led to the creation of soft wrought iron and homogeneous metal plates; chilled cast-iron blocks; Whitworth, Schneider and Terre Noire metal; and compound armor; except an idea be given of the internal changes and arrangements which take place in the metal when submitted to the different processes.

The material of which all armor-plates are made comes from the common metal basis, iron; and the qualities which the different kinds of plates possess are primarily due to the amount of carbon present in combination with the pure metal *and the arrangement of the combination of* carbon and iron. Dr. Percy states in his Metallurgy of Iron: "The influence of this element (carbon) in causing variation in the physical properties of iron is one of the most extraordinary phenomena in the whole range of metallurgy. Under the common name of iron are included virtually distinct metals, which in external characters differ far more from each other than many chemically distinct metals. When carbon is absent, or only present in very small quantity, we have *wrought iron*, which is comparatively soft, malleable, ductile, weldable, easily forgeable, and very tenacious, but not fusible except at temperatures rarely attainable in furnaces, and not susceptible of tempering like steel; when present in certain proportions, the limits of which cannot be exactly prescribed, we have the various kinds of *steel*, which are highly elastic, malleable, ductile, forgeable, weldable, and capable of receiving very different degrees of hardness by tempering, even so as to cut wrought iron with facility, and fusible in furnaces; and lastly, when present in greater propor-

tion than in steel, we have *cast iron*, which is hard, comparatively brittle and readily fusible, but not forgeable or weldable."

These metals contain other substances more or less affecting their qualities; chiefly phosphorus, silicon, sulphur and manganese; but all of these substances play but a subordinate part in the constitution of the metal itself. With regard to the absolute amount of carbon present in the metals and the effects which it produces, the German metallurgist Karsten lays down the following laws: It is considered that the maximum of carbon with which iron can combine is 5.93 per cent. When combined with carbon not exceeding certain limits, iron increases in tenacity and consequently in elasticity; as also in malleability, ductility and hardness. The last property is increased by sudden cooling after heating; and when it is considerable, as is the case in all iron containing more than from 0.2 to 0.25 per cent. of carbon, the metal is designated steel. The more free iron is from foreign matters, especially silicon, sulphur and phosphorus, the larger is the amount of carbon required to induce hardness by this treatment. The passage from iron into steel is so gradual and insensible that it is impossible to pronounce where one ends and the other begins. When, however, the carbon reaches 0.5 per cent. and other foreign matters are present in small quantity, iron is capable of being hardened sufficiently to give sparks with flint, and may then be regarded as steel. But in the case of iron perfectly free from foreign matters, not less than 0.65 per cent. of carbon is required to induce this property. Iron containing from 1 to 1.5 per cent. is steel, which, after hardening, acquires the maximum hardness *combined with the maximum tenacity*. When the carbon exceeds the highest of these limits, still greater hardness may be obtained, but only at the expense of tenacity and weldability. With 1.75 per cent. of carbon, weldability is almost completely lost. With 1.8 per cent. iron may still with great difficulty be worked and drawn out under the hammer, and although very hard, it yet retains considerable tenacity. When the carbon rises to 1.9 per cent. or more the metal ceases to be malleable while hot; and 2 per cent. seems to be the limit between steel and cast iron, where the metal in the softened state can no longer be drawn out without cracking and breaking to pieces under the hammer.

Before going farther it is necessary to get a full comprehension of the meaning of the terms used to express the different qualities. *Malleability* is the property of permanently extending in all direc-

tions without rupture, by pressure (as in rolling) or by impact (as in hammering). It is opposed to brittleness, which is the property of more or less readily breaking under compression, whether gradual or sudden. Malleability may be much affected by temperature, as in copper, which is malleable cold and up to a certain low heat, beyond which it becomes very brittle. Pure iron continues malleable even when near its point of fusion. Malleability is also affected by molecular condition. Thus, both iron and steel may lose their malleability by being hammered and rolled, and can only regain it by being heated to a certain point. When malleability is thus lost it is restored by what is termed *annealing*, or raising the metal to a high temperature and allowing it to cool very slowly.

Ductility is the property of permanently extending by traction, as in wire-drawing. Although all ductile metals are necessarily malleable, yet they are not necessarily ductile in the same ratio of their malleability. Thus, iron is very ductile, and may be drawn out into very fine wire; but it cannot, like some other less ductile metals, be hammered or rolled out into extremely thin sheets.

Tenacity is the property of resisting rupture by traction.

Toughness is a term nearly allied to tenacity, and denotes the property of resisting extension or fracture by tearing or bending. Thus, steel, whether perfectly hard or of the softest temper, resists flexure with equal force, when the deviations from the natural state are small. When its hardness is moderate it is capable of considerable curvature without alteration of form or breaking; and this quality is called toughness, and is opposed to *rigidity* and *brittleness* on the one side, and to *ductility* on the other.

Softness is the property of *easily* yielding to compression without fracture, and not returning to its original form after the removal of the compressing force. It is opposed to *elasticity*.

The brittle metals in common use always exhibit a well-marked crystalline structure, and when a fused metal is allowed to cool slowly it naturally is in a condition favorable to crystallization, while rapid cooling has the contrary effect. This effect is strikingly apparent in the treatment of gray pig-iron. If a portion of this metal be allowed to run from a furnace upon a cold slab of iron, so as to be cooled with extreme rapidity (chilled), its fracture will show a fine close crystallization; while if another portion from the same run be poured upon a hot slag, its fracture will show very large crystals, so different from the other as to appear like a different

material. As all iron is highly crystalline, it can be readily understood why pieces, which have been frequently and strongly heated, or which have been forged into large masses, and consequently have been subjected during a considerable time to a high temperature, should tend to become largely crystalline in structure. The operation of hammering iron while strongly heated, and during cooling to a certain degree, will obviously interfere with the action of the forces which determine crystalline arrangement, and may, consequently, be expected to diminish the size of the crystals. But in the case of large masses it will be difficult to affect the metal far below the surface, unless a very heavy hammer is employed. Thus, when the exterior may be cooled down to redness, the interior must still be at a much higher temperature, it may be white hot; so that on subsequent cooling, after the cessation of the blows, the particles in one part of the mass will be in a condition to assume a more largely crystalline structure than those in another part. It is this which constitutes one of the main difficulties in large forgings; and it cannot be overcome by continuing the hammering until the metal in the interior is sufficiently reduced in temperature to prevent the formation of large crystals in that part; for, if the metal on the exterior were hammered at too low a temperature, it would become brittle and tender. This, however, applies to iron and not to steel, or to iron containing any sensible proportion of carbon, as will appear farther on.

When iron is hammered cold, especially in various directions, the crystals of which it consists will obviously become more or less disaggregated, and therefore the strength of the metal will be diminished. The larger the crystals the more easily will the iron break; for, as fracture will occur in the direction of least resistance, which is that of the cleavage planes, it will be facilitated in proportion to the size of the planes.

It is frequently remarked as a phenomenon, that a bar of rolled iron when bent slowly to fracture, will exhibit a fibrous texture, while the same piece broken suddenly shows a strongly crystalline texture. In reality there is no marked phenomenon about it. By the operation of rolling, the crystals are drawn out *in one direction* into wires as it were, and the resulting bar will be composed of parallel and continuous bundles of such wires. But the crystalline structure is not thereby obliterated. Time plays a most important part in determining the character of the fracture. When the metal is broken with extreme rapidity, there is no time for the exercise of the property of ductility,

and the fracture will be necessarily crystalline; when rupture is slowly produced, there is ample time for ductility to act; and during the bending of the bar, the crystals of the convex side, in the place of flexure, actually undergo a process equivalent to wire-drawing, and so tend to develop fibre on fracture.

The property of *welding* that iron possesses is excellently described by Dr. Percy as follows:

Iron has one remarkable and very important property, namely, that of continuing soft and more or less pasty through a considerable range of temperature below its melting point. It is sufficiently soft at a bright-red heat to admit of being forged with facility, as every one knows; and at about a white heat it is so pasty that when two pieces at this temperature are pressed together they unite intimately and firmly. This is what occurs in the common process of *welding*. Generally, metals seem to pass *quickly* from the solid to the liquid state, and so far from being pasty and cohesive at the temperature of incipient fusion, they are extremely brittle and in some cases easily pulverizable. But, admitting that there is a particular temperature at which a metal becomes pasty, its range is so limited in the case of the common metals, that it would be scarcely possible to hit upon it with any certainty in practice; or if it were possible, its duration would be too short for the performance of the necessary manipulation in welding. Besides, there is another condition that might interfere with the process. In order that union should take place between two contiguous surfaces of a metal, it is obviously essential that they should not be covered with any infusible matter, such as scale due to oxidation. In heating iron to the welding temperature, a scale is formed, which may be immediately converted into very fusible and liquid silicate of protoxide by throwing a little sand over it, when welding may be effected, the silicate being squeezed out during the operation, and clean metallic surfaces brought together. Every blacksmith resorts to this simple expedient of using sand as a flux. But in the case of some of the common metals, it would not be very easy, or indeed practicable to find a suitable flux and to insure this condition. A piece of iron at a welding heat cannot be exposed to the atmosphere for an instant without acquiring a coat of scale, so that the use of a flux to liquefy it is absolutely necessary.

With regard to the terms *Scale*, *Flux*, and *Slag*, many who have made no special study of metallurgy have but a vague idea of their meaning, although no description of the manufacture of armor-plates

can be rendered intelligible without a knowledge of the terms. By scale is meant the film or coat of oxide that is formed on the surface of a metal when exposed to the air. The hotter a piece of metal is the quicker scale will form, and as it is almost infusible and very hard in character it prevents welding, by interposing its hard surface between the pasty surfaces of the pieces to be welded. Flux is the term applied to any material or mixture that will assist fusion. Thus sand is a flux for hot iron, as, when it comes in contact with iron scale, the action of the heat will fuse or melt the combination almost instantly, although the same heat would have no effect on the scale alone. The melted combination will run off the surface of iron, leaving it clean, and when this melted combination cools it is called *slag* or *cinder*. Different refractory substances require different fluxes to melt them, and this will be noticed in the process of *smelting* different iron ores; this technical term meaning simply *melting with the aid of a flux*. In order to get the pure iron from the ore as it comes from the mines, the whole mass is melted together, and as some of the rock in which the iron is imbedded, or the scale with which it is covered, is very refractory, the flux is thrown into the furnace to help melt it. In the liquid state, the different substances of course arrange themselves in the order of their specific gravities and thus the metal is separated from the slag. Since scale consists of good iron that has been affected by the oxygen of air, and since it is a source of waste by being turned into slag, it is readily seen how important it becomes to prevent the formation of scale in furnaces. This point being made clear, the differences in processes of manufacture of metal for armor can be understood.

As has been stated, the qualities which different kinds of plates possess are primarily due to the amount and arrangement of the carbon contained in the iron; and this is the most important point of all to be considered. Carbon exists in iron in two distinct combinations: 1st, as a simple mechanical mixture under the form of graphite, just as nitre exists in gunpowder. 2d, as a chemical combination making *steel*. Now, by different operations, a given amount of carbon may be made to enter the iron chemically or mechanically, and when there, it may be made to change from one condition to the other, or to divide partly in one and partly in the other. This is the secret of the different qualities given to the metal basis iron by combination with carbon, and to it is due the great confusion that has always existed as to the boundary line between wrought iron and steel; for iron may contain as much as 0.65 per cent. of carbon without showing a single

quality inherent to steel, thus being purely wrought iron; and again it may contain only 0.15 per cent. of carbon and still be clearly steel according to all the definitions of that metal. A singular and important feature with regard to carbon is this: Under the form of graphite it is of course a mechanical mixture, distinct from the iron, and it would be naturally supposed that when the iron was melted, the graphite, being lighter, would float on the surface. This is not the case, however, for it becomes dissolved in the molten mass. Taking for example a mass of molten cast-iron: It may be defined as a saturated solution of carbon in iron, with an excess of carbon in a state of mechanical mixture, or in other words, it is steel containing carbon in mechanical mixture. From this molten mass may be created either *white* or *gray* cast iron without removing any of the carbon. This is in a great measure determined by the conditions of solidification. Rapid solidification favors the retention of carbon in the combined state, thus forming white cast iron, which is carburized steel with a small amount of mixed carbon. Slow cooling on the other hand allows the carbon to return to its condition of graphite, making gray iron, which is slightly carburized steel with much mixed carbon. In the case of Gruson chilled plates the phenomenon is made beautifully apparent. The metal of one plate all comes from the same furnace-charge and the carbon is equally arranged throughout the molten mass. After cooling, however, the chilled side is the highest of white iron, gradually changing to mottled, and then to gray. If pieces from the different sections were analyzed they might be found to all contain the same absolute amount of carbon. This is a very important point; no part of the block is steel proper, for it contains too much carbon. If, as some have supposed, the differences in the metal were due to a transfer of carbon from one part to another, the result would be entirely different, for in that case, the portion containing the most carbon would be cast iron shading into steel, and finally to wrought iron.

The definition of cast iron is given above as steel containing carbon in mechanical mixture. Therefore, if the excess of carbon be driven out of the metal altogether, steel will be the result. This being done, the carbon remaining has the same tendencies to be affected by rapid and slow cooling as before, with the sole difference that the tendency may not be made *apparent* by the actual formation of graphite. This is of course natural as the surplus which made the graphite was driven off. Although not thus apparent, it is made evident by an alteration in the properties of the steel itself, and the conditions of

cooling by which the properties are changed are called *tempering* and *annealing*. Rapid cooling is called tempering and slow cooling is called annealing, and a piece of steel is hardened when it is tempered and softened when it is annealed.*

The phenomena of tempering and annealing are clearly described by Naval Constructor Barba of the French Navy, in an excellent little treatise on the Use of Steel for Constructive Purposes. His remarks are as follows:

"When any metal is tempered, that is to say, rapidly cooled, the external layer cools first, and it does this all the quicker as the difference in temperature between the body and the liquid in which it is immersed is greater. The conducting power of the liquid used has, also, a great influence on the rapidity of cooling; tempering in mercury, for instance, will be more intense than tempering in water.

"This cooled external layer contracts and presses strongly on the inside, which is yet at a high temperature; reciprocally, it receives from the inside the same pressure. Another phenomenon is a consequence of this contraction; in order to contain the internal volume, the external layers must stretch at the expense of their elasticity; if the tempering has been intense enough they may exceed their limit of elasticity and stretch permanently. If tempering has been incomplete or slight, this limit not being reached, the extension will be but momentary, and will disappear when cooling is complete.

"It is known that these phenomena are practically taken advantage of to break cast-iron blocks, which could not be easily affected by blows; they are heated red and cooled in a stream of water. The external surface contracts and passes its elastic limit; as it is capable of only slight stretching before breaking, cracks show themselves on the surface, and a comparatively slight blow is sufficient to break the block into several pieces.

"During the second period of tempering, the cooling spreads to the centre. In their turn, the central fibres contract on account of the lower temperature; but they are bound to the external fibres which have exceeded their limit of elasticity; they must then stretch at the expense of their elasticity as they contract; they at the same time cause a contraction of the external fibres.

* There is much in the association of ideas, and the writer has long treasured a grudge against good old Dean Swift for causing a confusion as to the application of terms, in that he did not consult his dictionary before giving to the world that beautiful sentiment so absurdly expressed: "He tempereth the wind to the shorn lamb."

"A tempered body is, therefore, subjected to direct forces which are balanced by molecular tensions. The forces which exist after tempering can be exhibited by suppressing a part of them. If a bar of tempered iron, squared on all sides, is cut in two longitudinally in a planer, care being taken to hold it in an invariable position, each of the pieces assumes, when left to itself, a curved form, the concavity of which is on the planed side. This form demonstrates a tension in this part, resulting from the second period of tempering. The forces brought into play in the first period would have produced the opposite effect if they alone had acted.

"Bodies increase in volume slightly when they are tempered; under the influence of an internal pressure a bar of iron behaves like any homogeneous body subjected to deformation by an internal force; it tends to assume the spherical form. The direction in which the increase takes place, however, depends upon the effect of previous treatment of the molecules. In a rolled bar, the crystals are elongated in one direction, therefore the first operation of tempering causes them to pass their elastic limit in this direction first, and so after tempering the bar is permanently elongated. A hammered bar may on the other hand be enlarged in width and height.

"Tempering should produce these effects in homogeneous bodies only, the composition of which does not vary with the temperature and pressure. In steels and other carburized irons, tempering is complicated by the presence of carbon, *the solution of which it partly brings about.* It is difficult to know whether the increase in volume observed in tempered steel is to a certain extent modified by this solution; by continuing the comparison between the laws of solubility of solids in liquids (Barba had previously shown that the laws of solubility of carbon in iron were the same as those of solids in liquids generally), we may suppose that the increase in volume does not result from this cause; for a solution never has a larger volume than the total volume of the bodies it contains."

The solution brought about by tempering steel produces a body endowed with properties different from those it possessed before tempering; but this body, at the time of sudden cooling, is always under the influence of the phenomena we have just explained. The pressure resulting from the two phases of tempering maintains in solution a part of the carbon that would have become separated by slow cooling; this portion will be greater as the pressure is stronger, and the tempering more rapid.

If a non-homogeneous body is tempered, composed for instance of steels at different degrees of carburization, the action will be complex; it seems probable that, when the body is hot, the carbon will be distributed a little less irregularly, and that this dissemination can increase only under the pressure of the cooled external fibres. If we suppose this body represented by different tints according to its amounts of carbon in different parts, the lines of demarcation, instead of being decided as in the original state, will be blended after tempering.

This phenomenon of transfusion of carbon through iron or steel heated to a sufficient temperature is well known. A bar heated with charcoal is cemented, or dissolves carbon, first on the surface, then more deeply, and finally to the centre if cementation lasts long enough.

When steel is subjected to different degrees of tempering, the carbon is kept in solution in a much larger proportion as the tempering is more energetic. With each class of steel there should correspond a degree of temper at which the maximum effect is produced, that is to say, when tempering would cause the solution of all the carbon contained in the steel. If the effort of contraction were the same for all steels, the intensity of temper producing this effect should increase with the degree of carburization. But the contraction or pressure due to rapid cooling is generally insufficient to produce this result. The more the rapidity of cooling is increased, the more the steel changes its properties. The least carburized steels only could be excepted; beyond a certain point the solving effect produced by an increase of intensity in tempering ought to be nothing; alterations in elasticity only could be observed. But, in these bodies, the limit of elasticity is reached under relatively slight effects, and tempering, by a variation of temperature such as we can effect, does not produce a sufficient pressure to dissolve all the carbon.

Tempered bodies generally regain their properties when they are annealed, that is to say, when they are made to cool slowly after being heated sufficiently. When a homogeneous body, the composition of which does not vary by heating, is annealed, the effect is merely to restore its original elasticity. To insure thorough annealing, the operation must be performed at a sufficiently high temperature, and the cooling must be slower as the size of the body is greater, so that there may be between the interior and exterior but a slight difference in temperature. The first condition is necessary to

allow the metal to recover the elasticity it lost in tempering; the second condition should prevent, in the successive phases of cooling, the production of undue strains.

In complex bodies like steel, the effect of annealing is complex; besides this restitution of elasticity to the fibres altered by tempering, it produces a separation of a part of the dissolved carbon. This separation must take place equally throughout the mass to render the body homogeneous after annealing; and it is easily understood that a very slow cooling is necessary to insure this result. For large pieces of steel this cooling must occupy several days, sometimes several weeks.

When steel is properly annealed the different molecular tensions previously produced are suppressed, the fibres relax under the influence of heat and return to their first elasticity.

If annealing is applied to a piece having undergone local tempering, the effect will be the same. In a bar made up of steels of different degrees of carburization, annealing will establish a little more homogeneity. Owing to the high temperature the bar will have to bear the lines of demarcation will no longer be as clearly defined, and the difference between the several parts will be less as the piece is exposed longer to the fire. In annealing this more regular dissemination of carbon is due only to the high temperature to which the piece is raised, while in tempering the effect is increased by the pressure resulting from rapid cooling.

Annealing must not be performed at too high a temperature—near the melting-point—lest the fibrous texture of the metal, acquired by forging, should be changed. Slow cooling would crystallize it, and it would then have no elasticity—*it would be* BURNED.

In the same steel there may exist a series of intermediate states between the natural state and the state corresponding to the maximum temper it can take. The several properties of the same steel follow a continuous law of variation between these two extreme points. In the natural state, steel possesses a hardness increasing as it contains more carbon and as it approaches more and more the maximum of saturation. Tenacity, or resistance to breaking, follows the same law, increasing in a continuous manner from soft iron to the hardest steel.

The stresses steel can bear before reaching its limit of elasticity follow the same law. On the contrary, the attainable stretching increases when the quantity of carbon, and, consequently, the hardness and tenacity, decrease. The welding property varies like the

stretching one, being very high in slightly carburized irons, and being reduced to almost nothing in steels rich in carbon.

When steels are tempered under the same conditions, hardness, tenacity, and stretching follow the same law that obtains in the natural state. Hardness and tenacity increase with the temper and ductility decreases. In short, the difference between a steel in the natural state and the same steel tempered is less as carbon decreases and as the metal approaches pure iron.

We will consider here only temper obtained by rapidly cooling steel, heated to a high heat, in a cold liquid. Under these conditions the changes of constitution induced by tempering should decrease as the operation is performed on less carburized steels. With very high steels the elastic limit is reached only under a very heavy load; with soft steels the elastic limit is much more quickly attained. The same degree of cooling will then produce a contraction and pressure much smaller in the second case than in the first.

From this statement we may conclude that when hardness and tenacity are required, and a material liable to deformation before breaking is not desirable, the highest or most carburized steel must be used. From this class is chosen the steel for tools that are not worked under blows. For constructive purposes where a more elastic material is needed, less carburized iron—in other words, soft steel, must be used. The following list of steel objects, with the percentage of carbon usually allowed, gives an excellent idea of the requirements:

Steel for flat files,	1.2	Steel for mason's tools,	0.6
" turning-tools,	1.0	" ramrods,	0.6
" cutters,	0.9	" stamping,	0.42
" chisels,	0.75	" magnets,	0.4
Die-steel,	0.74	" spades,	0.32
Double-shear steel,	0.7	" hammers,	0.3
Welding steel,	0.68	Bessemer rails,	0.25 to 0.3
Quarry drills,	0.64	Homogeneous armor plates,	0.23

We can conceive that tempering, followed by annealing, might be used to improve certain more or less carburized iron, especially to restore homogeneity lost in the different stages of manufacture.

"All merchant irons contain slight quantities of carbon, and consequently yield, but in a less degree, to the influences of tempering

and annealing. Heat produces in iron a more complete solution cf the carbon and a dissemination of that mixed in the metal; probably also of other foreign ingredients. The pressure which follows tempering increases this dissemination. Finally, while annealing, the heat continues the effect produced, and slow cooling allows the molecules to group themselves so as to nearly remove the several internal strains.

"In a great many cases tempering is followed by such an incomplete annealing as tends to lessen the molecular tensions, while preserving in the metal the greater part of the properties due to tempering, viz. hardness, tenacity, and also a more homogeneous composition. Afterwards more or less annealing is given according to the degree of elasticity which is to be restored.

"Partial annealing after tempering is used in armor plates. The tempering they undergo after rolling renders them more homogeneous throughout the mass by the compression it produces in every direction. Hardness, or resistance to the penetration of projectiles, is increased, but the metal becomes brittle as the tempering is more complete, or, with the same range of temperature, as the plates are thicker.

"Complete annealing would destroy all brittleness; but in order to preserve some hardness and prevent any internal crystallization, annealing is carried only to dark red. This temperature is insufficient to restore to the different fibres all their elastic properties, but it allows a preservation of the greater part of the hardness proceeding from tempering.

"In plates less than $\frac{3}{4}$ of an inch in thickness this annealing is sufficient for the purpose mentioned. The result is a metal able to withstand the penetration of projectiles and rarely breaking under their impact. In thicker plates submitted to tempering and annealing under the same conditions, the molecular tensions after tempering preserve more value after annealing. The plates satisfactorily resist penetration; they, however, have considerable brittleness. To avoid this defect it would be necessary to give more intensity to annealing. The plates would then offer less resistance to penetration, but they would no longer break under blows. (This is the principle followed by Schneider with his armor, as will be seen farther on.)

"The same result ought to be attained by reducing the intensity of temper. The heat to which the plates have to be raised cannot be lessened, since, in order to obtain homogeneity, a solution of all for-

eign matters in the iron must be produced; but the rapidity of cooling can be diminished by using a liquid which is a less good conductor than water, or by raising the temperature of this water. By this latter means the heated piece will be subjected at first to a rapid cooling to prevent separation of the carbon from its solution, then a much slower one, to prevent extreme molecular tensions."

Before proceeding to the detail of the different methods of armor manufacture, it is still necessary to explain the effects of the other different elements found in combination with iron. *Manganese*, in a limited proportion, is very beneficial both to iron and steel. By means of a suitable addition of metallic manganese to pig-iron it may be deprived of the sulphur and silicium which it contains, although it will not drive out phosphorus. Thus added to gray pig-iron it makes white, showing in this manner an influence over the carbon in keeping it in the distilled form. The same effect is produced on steel, enhancing the quality of the metal and augmenting its strength and ductility to a remarkable degree. It also augments the extent to which it is capable of being hardened or tempered. It eliminates oxide of iron or scale and thus preserves the welding limit of steel beyond what it would otherwise be, and prevents red-shortness or loss of malleability when hot. In the opinion of Dr. Siemens, however, more than a trace of manganese in steel is very objectionable; for, as he says, "though very efficacious in hiding impurities in the steel, it is in itself an impurity inconsistent with high quality of the material produced. Its admixture with the metal is purely mechanical, and upon analysis of different portions of the same ingot it is found that its distribution is very irregular. Being more oxidizable than iron, a metal containing a considerable percentage of manganese cannot be reheated without deterioration; is pitted by exposure to salt water, and its strength and toughness are also found to be below those of really pure metal when subjected to crucial tests."

This matter of pitting by exposure to salt water has long made shipbuilders afraid to use steel plates on the wetted parts of vessels, and they have erroneously held that *steel* deteriorated more rapidly in sea-water than iron. The pitting is entirely the oxidation of the manganese on the surface of a plate left as it came from the finishing-rolls. It is now the custom to give all steel plates an acid bath before applying them to ships, thus removing the surface manganese and other impurities which might cultivate oxidation.

Phosphorus is the worst of all impurities entering into combination

with iron. Its main influence seems to be to induce crystallization and thus cause cold-shortness, or loss of malleability when cold. The amount of injury done by phosphorus has been found by experiment to depend on the manner in which the iron is made; puddle iron is least sensitive of all, then comes malleable iron, whilst Bessemer steel is most affected. The cause of this seems to be that Bessemer metal contains the least slag, whilst puddle iron contains the most, and the intermingled slag renders the formation of a coarse crystalline structure more or less difficult according to the quantity of slag present. Carbon and phosphorus are direct enemies; thus if steel has 0.15 of phosphorus it will be made brittle by 0.3 of carbon, but with 0.05 of phosphorus it will not be made brittle by 0.75 of carbon. This material exercises an increasing bad influence when reheating is necessary, for the greater the amount of phosphorus the greater will be the tendency of the steel at every heat to assume the nature of iron. Phosphorus, in the same way as carbon, heightens the limit of elasticity, and increases the strength of the crystal particles, but it does not increase the cohesive power of separate crystals, so that since its tendency is to create large crystals, the metal is made weaker.

Sulphur increases the red-shortness of steel; that is, renders it less malleable when hot, and when steel contains above 0.2 per cent. of sulphur it breaks under the hammer at a low red heat. For the purpose, therefore, of making castings, a small amount of sulphur may be a positive advantage, as it increases the fluidity of the molten metal and gives toughness to the metal when cold. Sulphur is driven out of iron by manganese.

Silicon exercises a considerable effect on the qualities of steel, mainly beneficial to it. Its tendency is to produce the same effects as carbon, although in a very slight degree. It is the general rule to allow quite a large percentage of silicon to remain in cast steels, ranging from 0.1 to 0.3 per cent., rising in Krupp's cast steel as high as from 0.3 to 0.5 per cent. Its greatest service is the prevention of the formation of blow-holes in ingots. Bessemer states that "the air-cells existing in cast steel are due to the oxide of carbon formed in the liquid steel by an intermolecular reaction between the carbon of the metal and the oxide of iron formed during the act of casting. When the metal remains liquid sufficiently long, the gas escapes, but generally speaking, the temperature at which the steel is cast being only a little higher than that at which it solidifies, the carbonic oxide

remains imprisoned and gives rise to air-cells. Silicon prevents the formation of these air-cells, because it has a greater affinity for oxygen than carbon has, the oxidizing body being either peroxide of iron or carbonic acid or both; but then, instead of being gaseous, the product of the oxidation is a solid body formed in the metal itself, and is disposed uniformly between its molecules. It is the silicate of iron, the cinder interposed between the molecules, that renders the metal red-short and diminishes its quality as cast metal.

When the silicon exceeds 1 per cent., the behavior of the steel is quite peculiar. Large masses of the ingot melt out in the heating furnace, as if an easily fusible silicate had been formed, leaving deep holes, sometimes extending quite through the ingot, which do not weld together afterwards.

It is not necessary to enter into an explanation of the details of the work of extracting the iron from the ore, although it may be well as a matter of interest to show how it happens that although iron as it exists in the ore is in the condition of wrought iron, it is now almost universally supplied to the manufacturer in the condition of cast iron. The "rationale" of the extraction of iron from the ore has remained unchanged from the oldest times down to the present. In the old furnaces, which were naturally crude in their nature and limited in their capacity, the ore was reduced by means of a strongly carboniferous fuel, generally charcoal, burned in connection with a flux and aided by an air-blast of more or less strength. The flux uniting with the earthy impurities separated them from the mass as slag, and the carbon from the fuel uniting with the iron oxide set the metal free, which settled by its greater weight to the hearth of the furnace in the shape of a rough *bloom* of wrought iron. In this bloom were entangled many impurities, and as the contact of the carbon with the metal could not be equalized throughout the mass and the air-blast was difficult of regulation, the more highly heated portions of the pure metal absorbed or combined a certain amount of carbon, rendering the bloom as a rule steely and brittle, so that no amount of reworking would purify it.

With the invention of the smelting furnace and its companion, the puddling furnace, all the faults and uncertainties of this old or *direct* process of making wrought iron were remedied. In the modern smelting furnace the fuel, metal and flux are so arranged as to make the action of the heat and gases regular throughout the mass; the air-blast is made far more powerful and is used to a greater advan-

tage; whilst by the arrangement of the furnace, the *charging* or supplying with ore and fuel may be continuous, so that a single furnace may be kept constantly at work reducing ore for years without a single stoppage. By this second or *indirect* process, the pure wrought iron first separates from the impurities as before, but as it sinks in the furnace it becomes exposed to a higher heat; carbon combines with it, and, as the combination increases, the melting point is lowered until actual melting takes place. At this point, sufficient carbon has been combined to make the substance cast iron. It drops to the hearth, where the accompanying liquid slag floats on top of it and protects it from the decarbonizing influence of continued heat. From the hearth, the molten mass is drawn off into moulds and solidified into the blocks know as *pigs*. From these pigs are made wrought iron and steel. It is well to bear in mind that these first products, as they may be called, when of cast iron are known as *pigs*, when of wrought iron as *blooms*, and when of steel as *ingots*.

As cast iron is now the first product of the reduction of the ore, the first system of armor manufacture to be described is naturally that which is directly created from it.

Gruson Chilled Cast-iron Armor.

The first operation performed at the Gruson factory in the construction of an armored fortification, is to build a full-sized plaster model of the fort, each block being separately moulded and put in place. From this plaster cast, the exact shapes of the different curvatures are obtained, and the second part of the operation, that of making the chill mould, is then proceeded with. This chill mould is itself made of cast iron, which is run in an ordinary sand mould, the latter having been made from the plaster mould, and forms the base of the main block mould. Upon the chill mould a sand mould is built corresponding to the remaining end, side and interior contour of the block. What may be termed the trade secret in the construction of this armor rests entirely in the choice of the pig, its treatment in the furnace, and the care in the casting. Herr Gruson claims, and apparently with reason, that his factory is the only one in the world that can make such immense chill castings (ranging from 20 to 50 tons each) successfully. It is certain that the Russians tried repeatedly and unsuccessfully to make these castings without surface cracks; and when it is considered that it required years of practice to make perfect so small an object as a chilled 9-inch rifled shot, the skill and

knowledge required for the operation can be appreciated. The pig metal being melted in the furnaces, is tapped off into a single large receiver, and from there is fed directly into the mould. When the latter is full, a surplus of molten iron is allowed to run around the upper part of the mould so as to retard the cooling of the unchilled portion. When the casting is cooled, the work of the construction of the block is practically finished, for nothing remains except the ordinary finishing foundry work. The ends of each block are slightly hollowed, and when the blocks are put in position finally, zinc solder is run into the cavity formed by the close-fitting adjacent ends of blocks, securing them together and thus avoiding all bolts or fastenings of any other description.

Wrought-iron Armor.

The process of manufacturing a wrought-iron plate from pig iron may be divided into five distinct operations, viz. Puddling, shingling, rolling, piling, and final rolling or hammering. The operation of puddling is that in which the metal is converted from cast to wrought iron. The furnace for this work consists of a shallow basin in which the pigs are piled, which is so arranged that a strong flame plays constantly on the metal, melting it, and then burning the carbon from it. As the metal melts it is stirred constantly, so as to give the heat free access to all parts of it; and, as the carbon is burnt from it, it gradually changes from a fluid to a pasty mass. When the final condition of decarburization is reached, the metal is collected in rough balls weighing about 80 lbs. each, and these balls being withdrawn are *shingled*, that is worked under a hammer or in a squeezer, to weld all parts firmly together and to work out the slag and other impurities remaining from the furnace treatment. In the process of shingling the puddle-ball is roughly shaped into a slab, and then goes to the first or roughing rolls, where it is given fibre by repeated heating and rolling. According to the uses to which this mass may be put it is cut in pieces and rerolled until the desired fibre, size and shape are reached, the process of welding the pieces together after cutting being termed piling.

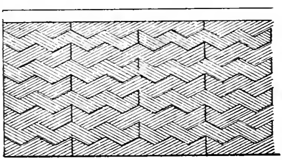
An excellent idea of the details of the process of making a wrought-iron 4½-inch plate is furnished by the evidence of Mr. Sanderson, Superintendent of the Park Gate Iron Works, given before the Iron Committee in 1861. A summary of this evidence is as follows:

"The pig iron was puddled in the ordinary way, and then the balls

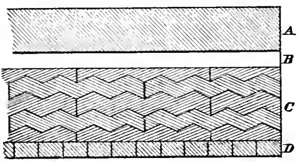
were shingled under a six-ton hammer, being transported from the furnace to the hammer on a carriage, in order to avoid picking up and incorporating dirt, small pieces of brick or stone, as would happen if the ball were dragged over the ground. By shingling, the balls were reduced to 12-inch bars, which were cut up and mixed for piles with similar scrap bars in the proportion of two-thirds scrap and one-third puddled iron. The pile was made from ten layers of these bars, and was rolled into what were called No. 1 slabs. In the piling the puddled bars were placed outside, on the top and bottom of the pile, as puddled iron rolled with a smoother surface than scrap; in rolling, the puddled bars were so placed as to roll across the grain, the other bars being crossed. All the scrap was from the waste and cuttings of other plates, great care being taken not to get in any outside unknown scrap, and this scrap was first worked into bars of the same size as the puddled bars. These No. 1's were rolled to an inch and a quarter thick, and then all the ragged edges were sheared off just as in a finished plate. Four of these inch and a quarter plates were then put together and welded into a plate 2¼ inches thick. This plate was then cut and piled into four layers and rolled to the finished dimensions of the 4½-inch plate. From the puddling to the finish there were five heats; the puddling being the first, the doubling of the No. 1's the second and third, the four No. 1's to make the 2¼-inch plate the fourth, and the four 2¼-inch to make the 4½-inch the fifth. In putting the 2¼-inch pile into the heating furnace, one of the plates was pushed in on to the sand bottom, the second was rolled in on top of it, and so on with the third and fourth; then, by means of a long lever, the ends of the pile were lifted, and bricks were put under the corners so as to give the flame free access to all sides. The plates of the pile were carefully matched so as not to lap at the sides or ends, or skew at all. About four and a half or five hours were required to thoroughly heat the whole mass, and before drawing from the furnace great care was taken to see that the whole pile was well heated, as, if one end was hot and the other cold, the rolls would be smashed in running the plate through.

"These rolls were 20 inches in diameter and 6½ feet long, and were fitted with reverse gearing so as to run the plate back and forth. They were directly in line with the mouth of the furnace and a short distance from it, there being a small carriage on rails travelling betweeen the two for carrying the plate. When the plate was at the

right heat, the carriage was run in place, the door opened and a large pair of tongs was slipped in, gripping the front end of the plate. The hauling-line from the tongs was then caught over the top roll like over a windlass, the rolls were speeded up and the plate hauled quickly out on to the carriage and up until its front end was nipped in the rolls and carried through. The time from hooking on until the plate was in the rolls was about half a minute. As the pile came out of the furnace a little sand was sprinkled over the surface for a flux, and as the pile ran through the rolls the cinder ran on the outer surface like a wave. The scoria flew away on all sides a distance of six or seven feet like liquid oil. The thickness of the pile at the last heat was about nine inches, and it was passed six times through the rolls under that heat. The first time going through it was pinched down an inch and a quarter. It went through instantly, squeezing all the scoria from the inside. Each time it was pinched a little less to relieve the rolls, the scoria running for about three times through. After rolling, the plate was straightened, then allowed to cool, and then the ends and sides were trimmed fair in the slotter and planer."



French Half Pile for Cover Plate.



French Half Pile for Finished Plate. A. Cover Plate. B. Bars. C. Zigzags. D. Bars.

In a previous chapter it was stated that during the first period of development of wrought-iron armor French plates were so much superior to English ones as to lead to the belief that they were really compound, having a steel core with an iron face and back. This superiority may be partially traced to the greater care taken in the selection of the ore, greater adaptability of various ores used, and more careful manipulation in the reduction. Another feature in the manufacture deserves notice, as it may have contributed much to the superiority of the plates. This was the difference in method of piling. It is seen that by the English method the puddled and scrap bars were piled in flat courses, the fibre being crossed in alternate courses. In the French method the plate was made up of two cov-

ering plates made separately, and an interior mass, the whole welded together. Each covering plate was formed of two half-piles, each of which was made of a foundation of iron bars covered by several courses of bars arranged in zig-zag, these bars crossing the foundation flat bars. The two half-piles having been raised to a welding heat are passed successively through the rolls, then superposed, heated and welded in the rolls. A complete pile was in general nearly the full width of the finished plate and about three times the thickness (instead of twice as in the English system). The plate itself was in turn made up of two new half-piles welded in the same manner and composed of a covering plate (*A*), a course of iron bars (*B*), several courses of bars zig-zagged (*C*) crossing the cross bars, and finally a course of flat bars (*D*). The covering plate was about one-sixth that of the finished plate. After the finished rolling the plates were carefully heated to a bright red, tempered and then annealed.

For a number of years it was a matter of dispute between English manufacturers as to the relative superiority of rolled and hammered plates, and although the question was finally decided in favor of the rolled ones, it is necessary to understand the process followed in hammering in order to have the requisite familiarity with the factory work. The process above described, as followed by the Park Gate Works, was that of rolling. As opposed to this, the evidence given by Mr. William Clay before the Iron Committee gives an excellent idea of the manufacture of hammered plates as carried out by the Mersey Works. A transcript of the evidence gives the clearest idea of the claims made for hammering. It is as follows:

Q. Then for plates of the size necessary for the Warrior, would you prefer hammering or rolling, in order to obtain the qualities best suited to resist shot?

A. Hammering, of course: we only know occasionally what is done; and the reports in the engineering world about the matter are different; some state that rolled plates are bad, and some that hammered plates are bad. I cannot conceive that rolled plates can be so good if the hammered ones are properly made. If they go upon the assumption of making the plates hard, and putting a nice polished face on them, then probably rolled ones would be better.

Q. To hammer a large plate, must you not weld it at several heats, one after the other?

A. Yes; I should get probably three large slabs of iron rolled, as the most economical, and the best way of getting the iron in the shape of

slabs. Three of those would be put together, and the commencement would be made in the middle; they would take out the middle first, and that would be hammered to the proper size of the plate, and then they would go towards one end, and then commence adding slabs of iron, probably half a ton at a time, and working it gradually lengthways.

Q. With a kind of scarf-joint?

A. Yes; and make it as solid as if it was one piece.

Q. Do you think you could depend upon the soundness?

A. Yes; a prudent hammerman would not put his iron on a thickness of less than eight or nine inches, or he would never get his scarfs safe.

Q. You would then reduce the thickness of the iron to the thickness required?

A. Yes; by hammering it all over, going gradually from one finished part to another.

Q. In the first place, would not repeated heating damage the structure of the iron?

A. No; because it need not be heated more than necessary, though, most probably, for plates, five times; and I have found, by experiments made for that purpose, that puddled iron increases in strength up to the sixth working, and from that it gradually decreases in strength, therefore, if we take new puddled iron to begin with, and work it five times over, we have it in about its strongest state; you get to the maximum.

Q. Then would the hammering it so much tend to make the iron hard, supposing that it is softness and toughness that we want?

A. Yes; it would make the iron dense and hard. The denseness, I judge, would be an advantage, but the hardness must be removed by annealing, when the plate was finished.

Q. Would annealing make a close-grained heavy iron soft?

A. Yes; there is the crystalline iron; and I have tried experiments, by taking a piece of iron and heating it to a little more than redness, and hammering it with a light hammer till it was cold, and breaking a portion of it off (and it was beautifully fibrous rivet iron), and, after cold hammering it, a piece broke off as short as glass; I have then taken the remainder of the piece and put it into the fire, letting it get red hot, and it broke quite fibrous again. That was the effect of cold hammering and annealing.

Q. The hammered plate must be more expensive, must it not, than a rolled one?

A. Less when you get to large sizes. If the Secretary of War made me an offer, and said he would give me a choice, I would prefer the hammer. I think I could make them cheaper with the hammer. I cannot conceive with regard to rolling plates of that immense size, that there is any machinery in the country which is calculated thoroughly to weld and unite them.

Q. You do not consider any evil consequences would result from hammering plates in the way you speak of?

A. No; especially if they are annealed after.

Q. As to rolled plates—would they be softer?

A. I think there would be little difference between them and hammered plates made of good fibrous iron. Large forgings are generally specified to be made of best scrap iron by engineers, but I believe that well-selected, good strong puddled iron—for the reason I have already stated—does become improved up to the sixth time of heating and working, and is better: because scrap iron may have been worked these six times before, and may have been gradually, as it were, going down hill on the other side of the scale."

The manufacture of the plate cannot be considered finished until it is bent to the curve required to fit the section of the ship. The average amount of curvature given may be taken at about 9 inches lengthwise, or "bend," and 2 inches crosswise, or "dish," with a corresponding amount of twist. There are three different methods of obtaining the curvature required, two of which are in use in England and one in France. The first English method is that of the hydraulic press. In this, a cast-iron slab of the requisite form is placed on the piston head of the press; upon this the armor plate is laid (outer surface down), and upon the plate are laid cast-iron blocks called "packing," also shaped to the curve. The piston then being forced upwards, the hot plate is dished to the required curve. The second system is that of the "cradle." In this the cradle consists of a heavy cast-iron bed-plate, to which are attached a system of vertical wood frames, bound at the top with longitudinal stringers. These wood frames have holes bored through them at convenient distances for the purpose of pinning heavy longitudinal timbers used as braces for wedging. Cast-iron shapes of the desired curvature are laid on the bed of the cradle, and then, wide strips being laid around the edge of the plate to protect the hot, soft metal from local deformation, wedges are driven in between the timbers pinned to the frames and the strips on the plate, thus forcing the plate to take the curve. This method

necessitates an adjustment of the plate in the hydraulic press after it is cold. In spite of this bad feature the cradle system is preferred as being quicker, cheaper, and more certain than the press system. By the French system the plate is laid on an anvil or bed-plate shaped to the required curve, and is then patted or lightly hammered all over its surface by a special movable steam-hammer. The curving is done during the last rolling heat, immediately after the plate is through the last turn of the finishing rolls. In France curving by the press is forbidden, as it is thought to strain the *nerve* of the metal too much.

Early Steel and Homogeneous Metal Armor.

It will be remembered that in a former chapter reference was made to experiments carried on at Woolwich in 1857 with steel plates made by the Mersey Company. The metal of which these plates was made contained from 0.75 to 1 per cent. of carbon, and it was called "puddled" steel, from the method of its reduction. Pig iron was placed in the ordinary puddling furnace and submitted to the same course of treatment as would be followed for the manufacture of wrought iron, the operation of burning out the carbon being stopped at the desired point, when the pasty metal was balled and shingled, then rolled into bars, and these bars were sorted according to the appearance of their fracture. The remaining details of the manufacture of a plate were the same as with wrought iron, except that where scrap steel was used it was necessary, as with the puddled metal, to sort it carefully. Steel plates or other large masses manufactured in this way were subject to great irregularities in structure. The judgment of the workman in detecting signs furnished by the reducing metal in the furnace and the skill of the person employed in sorting bars for the piles had to be blindly depended on, and even the greatest experience failed in the face of the immense masses required for armor plates.

Homogeneous iron was simply a name for a particular quality of crucible steel. (This name must not be confounded with homogeneous *steel*, which applies only to fluid-compressed or silicon steel, which is so made as to solidify without producing blow holes in the mass of the metal; the method of manufacture will be detailed farther on.) Crucible steel is obtained by melting iron bars packed in coke or charcoal dust in crucibles. The amount of dust packed with the metal determines the quantity of carbon that will be combined,

and the homogeneous iron was simply the crucible steel thus made, containing a low percentage of carbon. It is readily seen that by this process the quality of the metal could be determined with a greater degree of accuracy than by puddling, but for large masses the cost of production became exorbitant, and there was still a great factor of uncertainty due to the fact that the crucible being able to convert but a small amount individually, many of them had to be used to cast an ingot of the required size, whilst several ingots were required for a plate, thus the slight differences in quality of the metal of each crucible amounted to considerable when a large plate was in question. The ingots were forged into slabs just as the puddle balls were shingled, the other operations of plate-making being the same.

Steel and Compound Armor.

The Bessemer Process.

Steel cannot be said to have been capable of development as armor until the grand invention of the Bessemer process came to the aid of the manufacturer, enabling him to produce the large and homogeneous masses necessary to permit of the variety in plate manufacture which enabled the possibilities of the metal to be studied. It has been shown that steel was produced in one of two general ways,—either by burning the carbon out of pig iron, which was the common form in which iron was supplied to the market, or by combining carbon with wrought iron that had already been reduced from the pig. Bessemer saw that if it could be made possible to bring air into intimate connection with molten pig iron, the metal could be reduced much more quickly than by the puddling process, where the air only attacked the surface, thus necessitating a constant manual stirring of the mass. Furthermore, he discovered that when air was forced into the iron mass an excessively high rate of combustion, and consequent increase of temperature, were brought about, and this heat was so great that furnace heat was unnecessary. This being the case, it followed that the conversion of the pig could be stopped at any stage of the operation by stopping the blast which was the cause of the combustion. The well-known Bessemer Converter was the result of this train of reasoning. The converter, as it is called, consists of a large pear-shaped receptacle, built of boiler plate and thickly lined with a very refractory material. It is mounted on trunnions near its

centre of gravity, and is pierced at the bottom with tuyere holes (holes for the passage of an air-blast). The top of the converter is so shaped as to form a convenient uptake for the flame, throwing it into a chimney built near the position of the receptacle. The charge of pig iron intended for conversion is first melted in a furnace conveniently situated. When in condition for running, the converter is revolved to a horizontal position, and the molten metal is run directly into it. It is then righted, the blast being started at the proper time so as to prevent the metal from running down the tuyere holes. As this blast of air is forced through the body of the metal, violent combustion and ebullition take place. The condition of the metal in the converter at any time may be told in four ways: by the color of of the flame coming from the mouth of the converter, by the noise made by the boiling liquid, by the register of the number of cubic feet of air that have passed through the metal, or by the lines in the spectrum of the flame.

In the earlier times of the Bessemer manufacture it was the custom to gauge the quality of the steel by one of these signs or by all three combined, and, when the proper moment had arrived, the converter was revolved on its trunnions, the blast was cut off automatically, combustion ceased with the cut-off of air, and the conversion stopped. The metal was then run into a ladle which, after receiving the charge, was swung over the ingot-moulds, the latter being filled in rapid succession. Thus many ingots were produced, all of which being from the same run of metal, were absolutely similar in quality.

The quality itself of the metal was, however, often very unsatisfactory, owing to the uncertainty of the indications, and a modification of the method was introduced, by which the charge in the converter was reduced completely to the condition of wrought iron. In this state the blast was stopped by swinging the converter, and a certain measured quantity of pig, spiegel iron and ferro-manganese was introduced; that is, a known percentage of carbon and manganese was added to the charge. The converter was then turned back, blowing was resumed just long enough to ensure complete incorporation of the new charge, and then the metal was run off into the moulds.

Siemens-Martin Process.

Of the many methods for producing steel on the open hearth, that due to the joint inventions of the Englishman Siemens and the Frenchman Martin has come to be known in the manufacturing world

as *the* open-hearth process. Siemens' share in the invention is in the furnace itself and its attachments, by which, through a system of what is called the regeneration of heat, the waste heat from a furnace is, as it were, bottled up and made to do useful work. Gas is used instead of fuel also, and the lining of the furnace is so constituted that it will successfully resist the action of the high heat necessary to maintain iron containing but a trace of carbon, in a molten condition. Martin's share is in the method of producing steel by the gradual introduction of wrought iron and scrap steel into a bath of molten pig.

Perhaps the main distinctive feature of this process is the absence of a powerful air-blast. The furnace consists of a shallow dished hearth, with a low roof curved down at a sharp angle so as to throw the flame well down on the metal. Underneath the hearth or furnace proper, four large compartments are built, called regenerators. They are loosely lined with fire-brick so as to allow the heated gas free play all about the interior. When in use, these regenerators are so connected with the hearth that the inflowing gas and air pass through two of them into the hearth, over the metal, out through the other two into a culvert, and so into the air. In passing out, the waste gases give up their heat to the brick linings, and by means of valves the current of gas and air may be altered so as to pass through the heated chambers, taking up this stored heat, thence over the hearth and out the other chambers. In converting a charge, the direction of the current is changed about every half-hour, so that by means of the chambers the heat is retained in the furnace instead of going to waste, thus making a considerable saving in fuel. The ingress and egress ports of the hearth are so arranged that the gas used as fuel enters by the one next to the bath, and the air by the one farthest away, thus bringing the air next to the roof of the furnace and forcing the gas and flame down into intimate contact with the metal. The hearth being charged with pig, the gas flame and air are started, the charge is melted, and then the iron and scrap steel is turned into the bath in doses at intervals, as rapidly as the bath will absorb it. The proportion of metal thus turned in varies from three to ten times the amount of pig used, according to circumstances. One of the great advantages of this process over others is, that owing to the gas used as fuel and the great heat in the furnace, the supply of fuel may be stopped at any moment for some time without danger of cooling the mass too much ; samples of the metal may be withdrawn, cooled and examined to see that the condition is exactly what is desired. If the proper

state has not been reached, the operation can be proceeded with, and thus the greatest exactitude is reached in the production of any desired quality of metal. This process is the greatest rival of the Bessemer, and is better adapted for work of a high order, which it can turn out quite as cheaply as the other. It is a much later invention than the Bessemer, and is rapidly increasing in favor all over the world.

The Basic Process.

In all of the methods of producing steel, the vicious element, phosphorus, has been the great enemy with which the manufacturer has had to contend. Especially is this trouble apparent in the Bessemer and Siemens-Martin processes, where the percentage of phosphorus in the resulting steel is actually greater than that originally present in the pig. In order to overcome the difficulty it has always been necessary, until quite lately, to *refine* the pig by a special operation before using it in conversion. This refining added much to the expense, was a tedious operation, and at best did not produce satisfactory results. Within the past few years, however, a new and important modification, called the Basic process, has been introduced. This is not a distinct process, as will be seen, but is applicable to both the Bessemer and the Siemens processes with but a secondary alteration in the plant, the main method of conversion remaining the same in both cases. The principle of the improvement consists in the substitution of a new lining to the furnace or converter, whose influence on the molten metal tended to attack and take out the phosphorus. Since there is much waste of lining through the action of the phosphorus, it is the custom, after charging a furnace, to throw in a large amount of the same basic material, which the phosphorus attacks in preference to the lining. By this means it has become possible to completely dephosphorize steel in conversion both in the Bessemer Converter and the Siemens Regenerator.

The Whitworth Process.

One of the chief defects of the steel made by the Bessemer and Siemens-Martin processes consists in the blow-holes and air-cells produced in the ingots by the entanglement of air at the moment of pouring the metal, and the formation of gases by the sudden transfer from the furnace to the casting-ladle and thence to the ingot-mould. The lower the percentage of carbon in the metal the greater the injury

usually produced. The use of manganese is often resorted to for the purpose of preventing this "piping," as it is called, but as it is used in the form of a carbide, it is impossible to employ a sufficient quantity of manganese in the milder steels without introducing too much carbon. To get rid of the formation of these cells Sir Joseph Whitworth conceived the idea of forcing them out of the mass of molten steel entirely by means of pressure. The ingots as cast are in the shape of hollow cylinders, the mould-box having a core; in this manner a large escape-surface is given for the gas, which in no case has far to travel to reach a point of escape. The mould-box is made of cast steel of a strength sufficient to stand the heavy pressure inside. Around the inside of this steel cylinder are placed vertical cast-iron bars fitting quite closely, but having on their sides small grooves cut from front to back, while the rear edges of the bars are chamfered, thus making vents for the escape of the gas past the bars and up their rear edges to the open air. The inside of this mould is coated with a thick layer of very refractory sand, which, whilst it protects the iron bars from the fluid steel, is sufficiently porous to let the gas pass through. The core of the mould is made in the same way, with a steel core surrounded by cast-iron vertical bars, which in turn are coated with sand. This mould is centred under the annular piston of a hydraulic press. The metal is poured in, filling the mould, and immediately the piston is forced down with a pressure of about six tons to the square inch. As the piston strikes the surface the metal squirts up around it in a thin sheet, which solidifies almost instantly, thus closing the aperture tightly. The pressure is kept on the ingot until the mass has acquired considerable solidity, in order to keep the metal from getting internal shrinkage strains. By this pressure the column of metal is shortened about one and a half inches to the foot. It is still an unsolved problem why the gases escape, as the pressure must naturally act equally in all directions. It is beyond doubt, however, that they are forced out, as they burn for some time at the vent openings around the top of the mould. Fractures of metal cast in this way are extremely close grained in texture and perfectly free from flaws, so that much of the Whitworth ingot steel is equal to metal that has been thoroughly forged after casting.

The Terre-Noire Process.

This method has for its main object the elimination of blow-holes, and it accomplishes it in a manner which certainly appears more

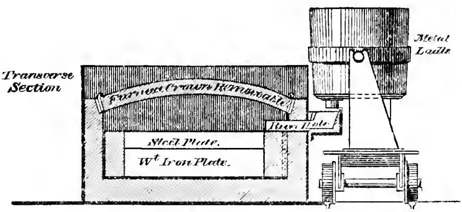
rational than the Whitworth process, in that it aims to prevent the formation of gas in the metal by the use of silicide of manganese. The silicon prevents blow-holes by decomposing the oxide of carbon, which is in dissolution and tends to escape during solidification. The manganese reduces the oxide of iron and prevents a further production of gases by the reaction of the oxide on the carbon. In the decomposition of oxide of carbon by silicon, silica was produced, and afterwards a silicate of iron, which remained in the steel, interposed between the molecules and preventing cohesion, which would be as bad for the metal as the blow-holes themselves; but the manganese allowed the formation of a silicate of iron and manganese, which is much more fusible and passes into the slag which floats on the metal. In this way the metal is not altered.

Euverte's conclusions from results obtained at Terre Noire are stated as follows: 1st. Steel derives the whole of its physical properties from its chemical composition and molecular state. 2d. Mechanical operations, such as forging and rolling, are not necessary to the production of the best results as to quality, and steel which has been cast without blow-holes in a suitable manner and reheated and tempered in the right way attains a perfectly satisfactory molecular state, which makes it applicable for all purposes. This may seem paradoxical at first sight, but numberless experiments have given results which seemed to be guided by an immutable law.

The Armor Plates.

In examining these various processes used in the production of steel, it is seen that either one alone, or a combination of them, may be used in producing the metal of a plate. Thus a manufacturer may use the Bessemer process combined with the Basic process for eliminating the phosphorus, and supplemented by the Whitworth process to obtain homogeneity of structure. This combination of processes forms one of the trade secrets of the manufacturer, in addition to which must be counted the niceties of refining and manipulation. It is therefore no criterion of the absolute excellence of steel plate to know simply that it is manufactured by one or another of the different processes. Beyond this lies the detail of manufacture, and the excellences of the plate can only be ascertained by actual test. Again, chemical analysis of specimens of a plate, although of the greatest use in the study of steel armor, tells no tale of the process of manufacture. It is, however, a matter of interest to know at least

what *main* processes are followed by the different manufacturers. At Terre Noire the metal for plates and projectiles is converted from pig iron by a combination of the Siemens-Martin and Terre Noire systems .Krupp, in the manufacture of guns, projectiles and armor, uses the Crucible process, in combination with a refining by the use of a high percentage of silicon and manganese, closely approaching the principle of the Terre Noire process. In fact, the latter is derived directly from the study of remarkable results obtained by Krupp and other German manufacturers by the use of heavy charges of silicon. Landore uses the Siemens-Martin process. Schneider uses at Creusot the Siemens-Martin process—in all probability combined with the Basic process. The immense plant of this firm enables the manufactürer to realize the full benefits of thorough forging in the large masses. The immense steel armor plates, having been moulded into the required ingots, are put under the 100-ton hammer and there forged to shape. Hammering is the rule for armor plates at Creusot, and, as was explained in the quoted evidence of Mr. Clay, of the Mersey Works, the finished plate is carefully annealed after the last working, then raised to a high tempering heat, and the face of the plate for a short distance is tempered in oil, and then, finally, partially reannealed, in order to take out the internal tempering strains without reducing the face-hardness more than necessary.



Wilson's Armor-plate Furnace.

The steel face plates of compound armor are manufactured at Brown's works by the Bessemer process, and at Cammel's by the Siemens-Martin. These two firms, besides using different processes in the manufacture of the steel, have also different methods of building up the compound armor, each method being the invention of the Superintendent of the firm. The one used at Cammel's foundry is known as Wilson's patent, and the one at Brown's as Ellis's patent.

This explains an apparent confusion with regard to armor which is called either by the firm's or the patentee's names.

Under the Wilson patent (Cammel) the iron backing plate is first manufactured in the ordinary way. It is then placed in a special furnace and raised to a welding heat, and while in this condition, without being removed from the furnace, molten steel, manufactured in this instance by the Siemens-Martin process, is poured on the plate to the requisite thickness. The steel has a much higher temperature than the iron, and the excessive heat carburizes the iron surface to a depth of from one-eighth to three-sixteenths of an inch, thus forming a zone of mild steel between the hard steel and the iron, while at the same time the connection between the steel and the iron is something more than the ordinary weld. After running the steel, the plate is removed from the furnace and put through finishing-rolls to insure thorough welding. The steel face is then tempered and partially reannealed to remove the internal strain.

A slight modification of the above method is said to have produced excellent results, in that the iron plate was placed on end in the furnace, the steel being run in alongside, thus gaining the additional factor of closeness of structure due to the additional weight forcing the gases out of the metal. It will be seen that the furnace itself is the mould for the plate.

Under the Ellis patent (Brown) the iron backing is manufactured as before, and a hard steel plate is also made separately. The iron plate is then put in a furnace similar to the Cammel one, and iron bars are placed around the edges, forming a berm. The hard steel plate is also put in the furnace, and all are raised to a welding heat together; the steel plate, which forms the face of the complete plate, is then laid over the berm of the iron one, and molten steel (Bessemer) of a medium softness is run between. The same welding action takes place as before, and the same system of rolling, tempering and annealing is followed.

It needs no demonstration to prove that the end of the development of compound armor has by no means been reached. As yet, there is a decided liability of the plate when struck by a projectile to separate at the weld, but this fault cannot be considered irremediable. The final aim of both the steel and the compound armor manufacturers is to put their plates in a condition corresponding to that of the Gruson blocks; having an extremely hard surface of steel proper, shading gradually and imperceptibly into a softer material. At present, the

steel manufacturer finds it impossible to get the extremely hard surface obtained in compound armor, whilst on the other hand a steel backing cannot be utilised by the compound manufacturer on account of the difficulty of welding. It would seem that the true line of development would be that which by manufacture and not by building should attain the final result of making a complete steel plate which should combine the hardness of the present compound face with the tenacity and resisting power of the rear of the present steel plate. Homogeneity of structure is the prime necessity of the development. In this respect the steel plate is in advance of the built-up compound one, but homogeneity alone is insufficient. For these reasons it is, and probably will be, for some time to come, especially with thick plates, a matter of dispute as to the absolute superiority of the two systems.

Laws of Penetration.

A knowledge of the laws governing the destructive action of projectiles in piercing armor is quite as necessary as that of the actual effects shown through firing-ground experiments. These laws depend upon the following circumstances:

1st. The resisting power of the armor, as determined by the qualities of the metal plates, the disposition of the backing, and the distribution and strength of the fastenings.

2d. The nature of the projectile: its form, weight, strength, and striking energy.

In the chapter descriptive of the development of wrought-iron armor it has been shown what were the consequences of adopting a metal which, with but a fair degree of tenacity and a minimum of hardness, possessed good toughness and a maximum of ductility. Necessary as these latter qualities are, they must in the nature of the conflict be subordinate to the first ones in true armor. Toughness and ductility are qualities which tend to preserve armor. Hardness and tenacity tend more directly to preserve the objects to be protected, for these are the ones which turn useful energy to waste by making it react on the projectile itself. As long as they were left out of consideration the balance of power could only be preserved by armor through a constant increase in thickness of plates; and aside from the difficulties of manufacture, the point was soon reached with war vessels where no more weight could be sacrificed (required for

other essential features) to secure armor strength. The following table shows clearly what great sacrifices were borne, before the minds of the experts were turned into the channel of the true line of development by the Spezia experiments of 1876:

Name of Ship.	Composition of Armor.	Total Weight of Armor.	Weight per Square foot.	Proportion of Displacement to Armor.
Warrior, ...	4½ iron—18 teak.	1354	284	6.38
Minotaur, . . .	5½ " 10 "	2106	297	5.08
Bellerophon, . .	6 " 10 "	1273	383	5.93
Hercules, . . .	9 " 22 "	1949	511	4.45
Alexandra, . . .	12 " 12 "	2348	645	4.00
Glatton, ...	14 " 15 "	1965	660	2.50
Devastation, . .	12 " 18 "	2961	664	3.15
Dreadnought, . .	14 " 15 "	3666	751	2.95
Inflexible, . . .	24 " 17 "	3553	1150	3.26

With regard to the disposition of the backing, it has been shown how, starting with the natural thickness of wooden frames and planking, it was found detrimental to attempt any reduction of that thickness, and shortly afterward, through the experiments on the Chalmers target, it was found that notable increase in power of resistance was obtained by means of the insertion of iron stringers between the courses of timber.

In the same way the faults of the first crude system of fastening were gradually corrected, until by the introduction of the Schneider bolt this part of the armor seems to have well-nigh reached perfection.

In form of projectile, the spherical figure gave way to the cylindrical with a hemispherical head, then the flat face, then the cone, and finally the ogive; which in turn, commencing with a radius of one calibre, passed to one and a half, and finally to two. The weight of the armor-piercing projectile, commencing with the round shot as a standard, has passed to that of an elongated one over 2½ times that weight, the standard rising slowly to three times and in cases to four times that of a sphere with a diameter of one calibre.

In strength, cast iron gave way to wrought iron, the latter to chilled cast iron, and now development has reached steel, which will constitute the metal of the armor-shot of the future. Steel, as has been shown, was successfully used during the earliest period of development; the

metal being crucible steel toughened and hardened by forging and tempering. The great cost of these projectiles, however, forbade their use until the great improvements in the methods of steel manufacture so reduced the price as to render a development of this type of weapon possible. At present great rivalry exists between the representatives of the three great systems of steel-making—the crucible process supplemented by thorough forging and tempering, the fluid compressing process, and the homogeneous casting (Terre Noire) process. As yet, projectiles made by fluid compression are unequalled for hardness and tenacity. Although chilled cast projectiles for armor penetration must give way in the near future, they hold their own well in the struggle, giving excellent results and at a minimum of cost.

As a very natural result of all these rapid changes and developments, it has been a matter of the greatest difficulty to establish any laws that would show even approximately the relation of striking energy to penetration. It has been, in fact, impossible to derive formulas that should be more than empirical. Before the introduction of armor General Didion had investigated thoroughly the conditions of the penetration of both spherical and elongated projectiles into earth, wood, and masonry, and established formulas that have needed but little correction since.

Mr. Fairbairn, while a member of the Committee on Iron, was the first to undertake a thorough investigation of the conditions of penetration of projectiles into iron plates. The theories which he deduced were based upon statical experiments, by punching iron plates under the machine; using cast, wrought, and steel punches with round and flat ends.

He found that the point of rupture of a good plate of a thickness up to 4½ inches might be assumed as equal to the thickness of the plate; also, that the statical pressure required in punching varied approximately as the area of the metal in the section sheared, that is, as the circumference of the shot multiplied by the thickness of the plate. Starting then with the hypothesis that the work expended by a shot in piercing a plate was equal to the striking energy (that is, that the destructive power of a shot was not its *momentum*, as was then popularly believed, but its *energy*), he deduced a formula for the penetration of the form

$$t=\sqrt{\frac{Wv^2}{Cr}}$$

in which t is the thickness in inches to be penetrated, wv^2 is the en-

ergy, r is the radius of the projectile, and C is a constant to be determined by the results of actual experiment. He then collected all the results of the firing experiments that had been made at Shoeburyness during the year, and from them found the maximum thickness of plates that could be pierced by Armstrong rifles of calibres from the 6 pdr. to the 40 pdr. Substituting these values for t in the above formula, he found a value for the constant C. This first trial constant was not very close to the truth, as might be expected, owing to the lack of sufficient experimental data on which to work. Several important points, however, were established. It was found that the actual experiments on the firing-ground corresponded very closely with those of the punch in the machine. This was a very important point, as it led to quite a radical difference in the method of estimating the resistance. With the soft substances experimented on by Didion the action of the projectile was wedge-like, so that the resistance was estimated per *square unit of area* of cross-section. On the other hand, the close correspondence of experiment on armor to the action of the punch led to the estimation of resistance as per *linear unit of circumference* of cross-section.

It will be noticed by reference to the above formula that Fairbairn considered the resistance to penetration to vary as the square of the thickness of the plate. This point is the main one that never has been satisfactorily determined. In his report for 1862 (the year after his first report) Fairbairn suggested that the resistance did not vary exactly as the square of the thickness, and he modified his formula to correspond to the results of experiments:

$$t = \left(\frac{Wv^2}{Cr}\right)^{\frac{1}{1.74}}$$

Several new points of great importance were developed by the statical experiments of this year, which deserve notice from the verification which the very latest experiments have given them. Fairbairn states in his report:

" It is evident that the round-ended shot loses more than half its powers of resistance to pressure in the direction of its length ; this may be accounted for by the hemispherical end concentrating the force on a single point, acting through the axis of the cylinder, and thus splitting off the sides in every direction. On the other hand, the flat-ended shot have the support of the whole base in a vertical direction.

"It has been correctly stated, that it requires a considerable amount of force to break up shot when delivered with great velocity against an unyielding body, and it may be thence concluded that the force expended in thus breaking up the shot must be deducted from that employed in doing work on the plate. This is confirmed by experiment, which shows that though the whole force contained in the ball, when discharged from a gun at a given velocity, must be delivered upon the target, the amount of work, or damage done to the plate, will depend on the weight and tenacity of the material of which the shot is composed.

"If, for example, we take two balls of the same weight, one of cast iron and the other of wrought iron, and deliver each of them upon the target with the same velocity, it is obvious that both balls carry with them the same projectile force as if they were composed of identically the same material. The dynamic effect, or work done, however, is widely different in the two cases, the one being brittle and the other tough. The result is that the cast iron is broken in pieces by the concussion of the blow, whilst the other either penetrates the plate, or, what is more probable, flattens its surface into a greatly increased area and inflicts greater punishment upon it. In this instance the amount of work done is in favor of the wrought-iron shot; but this does not alter the condition in which the force was in the first instance delivered upon the target, but is entirely due to the superior tenacity of the wrought-iron shot to that of the cast iron, which yields to the blow and is broken in pieces in consequence of its inferior power of resistance. The same may be said of steel in a much higher degree."

In comparative experiments made with wrought-iron and steel punches, Fairbairn estimated that a wrought-iron shot lost about $\frac{1}{25}$ of its power of penetration, from yielding to pressure and spreading itself over a larger surface.

In conclusion he says: "From these results and the coincidence which appears to exist between the mechanical force of impact and statical pressure, we arrive at the conclusion that any description of shot and shell intended for the penetration of armor plates *should be of hardened steel*, sufficiently tenacious not to break in pieces, and yet so hard as to resist compression."

Three or four years after this work of Fairbairn's a formula slightly different in shape, and with perfected coefficients, was worked out by Major W. H. Noble, Royal Artillery, and was adopted by the Government. The general expression was:

$$E = k.s.^x$$

E being the energy in foot-tons per inch of circumference; s the thickness of plate in inches and k a constant, whilst x represented the proportion in which penetration varied with regard to the thickness of the plate, which, as has been shown, was first declared by Fairbairn to vary as the square, and afterwards as the 1.74 power. The formula as applied was:

$$S=\left(\frac{E}{2.53}\right)^{\frac{1}{1.6}}.$$

It was found, however, with more extended experiments with high velocities and thicker plates that this formula was quite deficient in accuracy, so that a few years ago it was modified to the form

$$S=\left(\frac{E}{0.86}\right)^{\frac{1}{2.165}}.$$

Even this formula is unsatisfactory, and Colonel Inglis has prepared another formula, which Captain Orde Browne has reduced to one of the same form, except that the square root of E is taken, and the coefficient (of course, different) is not constant, but varies slowly with variations of the proportion of the diameter of the projectile to the thickness of the plate.

$$S=\sqrt{\frac{E}{c}}$$

c being found from the following table:

Ratio of thickness of plate to diameter of projectile.	Corresponding value of c.	Ratio of thickness of plate to diameter of projectile.	Corresponding value of c.
.5	1.300	1.3	0.981
.6	1.250	1.4	0.964
.7	1.178	1.5	0 950
.8	1.125	1.6	0.938
.9	1.083	1.7	0.926
1.0	1.050	1.8	0.917
1.1	1.022	1.9	0.908
1.2	1.000	2.0	0.900

This formula is the simplest yet devised, and, doubtless, the most correct, as in default of a regular law, which could not be applied on account of the differences of manufacture of plates and different conditions of firing, this sliding scale coefficient will produce results closer to the actual firing results.

To Captain Orde Browne is due the credit for a simple rule of

thumb for penetration, which is of great value in making rough estimates. This rule is: that the penetration of projectiles into wrought iron is one calibre for every thousand feet of velocity.

When the armor is penetrated by oblique fire, it is generally found that the projectile turns and penetrates nearly at right angles, the normal factor of the energy per inch of shot's circumference is then $\frac{E}{\sin^2\theta}$, which result, substituted for E in the foregoing formulæ, gives a very close result for angles up to an inclination of 45° from the vertical.

The formula derived by the Italians, for thick armor, from the Spezia trials is of the same form as the Noble one, differing only in the coefficient expressing the ratio of thickness to energy. It is:

$$S=\left(\frac{E}{4.154}\right)^{\frac{1}{1.4}}$$

The Gavres formula is put under a somewhat different form, and is more convenient where it is desired to ascertain the velocity of any projectile necessary to pierce a given target. For wrought iron and wood backing both are put under the same form, as follows:

For Iron.	*For Wood.*
$W=1600E\sqrt[0.7]{\frac{a}{p}}$	$U=95e\sqrt{\frac{a}{p}}$

$$V^2=W^2+U^2$$

$W=$ Velocity in metres.	$U=$ Velocity in metres.
$E=$ Thickness of plate in decimetres.	$e=$ Thickness of wood in decimetres.
$a=$ Diameter of shot in decimetres.	$a=$ Diameter of shot in decimetres.
$p=$ Weight of shot in kilogrammes.	$p=$ Weight of shot in kilogrammes.

Krupp uses a formula which is somewhat different from the others, and is quite simple in character.

$$L=\frac{S}{10}\sqrt[3]{\frac{S}{2r}}$$

$2r=$ calibre of shot in centimeters, $S=$ thickness of plate in centimeters, $L=$ energy in metre-tons per square centimeter of area of projectile necessary to pierce the plate.

It has been considered that in applying these formulas to compound and steel armor an allowance should be made of from ten to twenty per cent. greater energy for piercing; the rapid increase in quality of plates during the past year raising the percentage quite to the latter limit. From the last Spezia trials, however, as well as from those at Ochta, it has been decided that an entirely new departure must be made in determining the law of *destruction* and formulating it. Such a formula cannot be determined for some time yet, as it requires a great number of experiments from which to gather the data; and much of the data available, indeed the greater part of it, is practically useless, from the varying conditions of plate and projectiles.

Tests for the Reception of Armor Plates.

In order to ensure the excellence of all armor plates used in the construction of an ironclad, it has always been the custom of different governments (except the United States, where the precaution has been entirely neglected) to submit a certain number of plates to a series of tests, chemical, mechanical, and firing. The chemical analysis and mechanical tests are generally made on specimens taken from the scraps of *every* plate as a check to regularity of manufacture. As the firing-test destroys the plate experimented on entirely, it is limited to one plate, taken at random from each lot on delivery; the number of plates forming a lot differing according to circumstances, such as thickness, size, or conditions of manufacture. In a former chapter, a description was given of the first crude method established in France, which simply made the chemical and mechanical tests the standard guides.

For the acceptance of the plates of the Gloire and other ships of her date, one plate in every delivery of fifty was taken, and three shots were fired at it from the French 68 pdr. smoothbore (*canon de* 50) with a charge of 17 lbs. of powder at a range of 25 yards. The plates were to stand this test without being pierced or showing any cracks. In 1863, when the Provence type was built, the test was slightly altered by reducing the allowance of maximum penetration. In 1866, for the delivery of the plates of the Alma type, the plates were required to receive as many projectiles as there were times 60 square centimeters on the surface of the plate; all fractions to demand an extra shot; the plate to show no signs of cracking. With the advent of 9-inch plates new rules had to be established, and for this thickness and over, the French 9½ inch (24 centimeter) rifle was used, firing one

shot for each square metre of surface of plate; the charges varying from 35 lbs. for the first shot to 52 lbs. for the last, with a flat-ended cylindrical projectile, no cracks being allowed and no piercing; the range being 75 yards. The 24 centimeter gun was then adopted for all tests, with varying powder charges for the different thicknesses of plates. All plates received one shot for each square metre of surface, the projectiles for the heaviest plates being cylindrical, and spherical for all others. The charge for thick plates was 35 lbs. of powder, and for others 24 lbs. Plates under 5 inches were tested with the smooth-bore 68 pdr. under the old rule.

In England, the 68 pdr. was used in testing plates for reception until 1870, when the 7-inch rifle was substituted. The range was uniformly 10 yards, each plate to receive 4 shots without cracking or piercing. The charge varied with the thickness of the plate, as follows:

12-inch plate, 21 lbs.	10-inch plate, 17 lbs.
11 " " 19 "	9 " " 14 "

The introduction of compound and steel armor required a complete alteration in these reception tests. England first established a test-rule, upon the supposition that compound plates might be about 20 per cent. thinner than a wrought-iron plate of equal resistance, the calibre of gun, charge, &c., to be used in testing are such as would cause perforation of an iron plate 20 per cent. thicker than the compound one. The range is established at 10 yards and three shots are fired, each projectile falling upon the point of an equilateral triangle, having sides of two feet each, described upon the middle of the plate. The first shot must not produce any through-cracks and none of the shot must get through.

This test was adopted universally and was used up to the date of the last Spezia trials, which, it will be remembered, were for the purpose of establishing a test-rule for the heavy plates of the Italia. The rule established by this test, and which has now been adopted in England and France, is, that a single shot shall be fired against the centre of the plate, with a striking energy sufficient to pierce a wrought-iron plate of 25 per cent. greater thickness. The shot not to go through the plate, and no piece of the plate to be detached from the backing. This rule is for thick plates only, the other one still holding good for plates up to 12 and 14 inches in thickness.

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NAVAL INSTITUTE PRIZE ESSAY, 1884.

A Prize of one hundred dollars and a gold medal is offered by the Naval Institute for the best Essay presented, subject to the following rules :

1. Competition for the Prize is open to all members, Regular, Life, Honorary and Associate, and to all persons entitled to become members, provided such membership be completed before the submission of the Essay. Members whose dues are two years in arrears are not eligible to compete for the Prize until their dues are paid.

2. Each competitor to send his essay in a sealed envelope to the Secretary on or before January 1, 1884. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges to be three gentlemen of eminent professional attainments (to be selected by the Executive Committee), who will be requested to designate the essay, if any, worthy of the Prize, and, also, those deserving honorable mention, in the order of their merit.

4. The successful essay to be published in the Proceedings of the Institute, and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Executive Committee.

5. Any essay not having received honorable mention, to be published only with the consent of the author.

6. The subject for the Prize Essay is, "*The best method for the reconstruction and increase of the Navy.*"

7. The Essay is limited to forty-eight printed pages of the "Proceedings of the Institute."

8. The successful competitor will be made a Life Member of the Institute.

9. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

CHAS. M. THOMAS,
Secretary.

ANNAPOLIS, MD., *May* 3, 1883.

Vol. IX., No. 4. 1883. Whole No. 26.

PROCEEDINGS

OF THE

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VOLUME IX.

OUR NEW CRUISERS.

BY

Assistant Naval Constructor F. T. BOWLES, U. S. N.

PUBLISHED QUARTERLY BY THE INSTITUTE,
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List of Plates.

Chicago.

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// THE PROCEEDINGS

OF THE

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NAVAL INSTITUTE, ANNAPOLIS, MD.

SEPTEMBER, 1883.

OUR NEW CRUISERS.

BY ASS'T NAVAL CONSTRUCTOR F. T. BOWLES, U. S. N.

Secretary to the Naval Advisory Board.

Before entering upon the description of the cruisers just laid down for the Navy, it may be interesting to recall briefly the events which led to their production.

In June, 1881, the Hon. William H. Hunt, Secretary of the Navy, recognizing "the pressing need of appropriate vessels in the service," appointed an Advisory Board, consisting of fifteen officers, selected with care from the constructing and executive corps of the Navy, and presided over by the late Rear-Admiral John Rodgers.

Four months' time was allotted to the Board to consider and report upon the number of vessels which should now be built, their class and size, material and form of construction, nature and size of machinery for each, ordnance and armament, appropriate equipment and internal arrangements. This would have been a tremendous undertaking for a body of experts accustomed to working in concert, but doubly difficult for such a Board. The report, which was incorporated by the Secretary in his annual report to Congress, passed over the subject of ironclads as not a present necessity and requiring more careful con-

sideration and more intimate knowledge of modern practice than time would permit them to enter into or acquire. The necessity of reconstructing the cruising fleet was forcibly presented, and the general opinion of the Navy and the country well represented by the recommendation that thirty-eight unarmored cruisers of different classes should be built, which would have provided at the end of eight years a peace navy of seventy cruisers, of which about twenty would have been fair commerce-destroyers in time of war. The war navy was for defence only, and was to consist of five rams, five torpedo-gunboats, and twenty fast torpedo-boats.

The details of the report formed a rich field for criticism, both as to fact and opinion, and was the subject of much discussion in the press and in naval circles during the following session of Congress. The Naval Committee, led by the Hon. W. B. Harris, of Massachusetts, sifted the matter carefully, interrogated the members of the Board individually, and examined the shipbuilders and steel-makers of the country and many naval officers. In March, 1882, the committee reported to Congress, setting forth more clearly even than had been their custom for the preceding six years, the humiliating condition of the Navy, and recommended that six of the larger cruisers, one ram, and eight torpedo-boats be built. The bill presented therewith unfortunately contained measures making radical changes in the personnel and administration of the Navy, which prevented it from obtaining a hearing. Finally, owing to a political difference between two committees of the House, no appropriation was made for the increase of the Navy; but the Navy bill authorized the construction of one each of the two larger classes of cruisers recommended by the late Advisory Board, from any unexpended balance of the appropriation for the Bureau of Construction and Repair. This act created the present Naval Advisory Board, consisting of five officers of the Navy and two civilian experts. It requires the Board to advise and assist the Secretary of the Navy in all matters referred to them relative to the designs, plans, etc., of the vessels authorized to be built, makes the approval of the Board necessary for all such plans before work can be commenced, and gives the Board general supervision of the construction and trial when complete, under direction of the Secretary of the Navy. This Board was organized in November, 1882, with Rear-Admiral R. W. Shufeldt as President.

Congress, at the last session, upon the recommendation of this Board and the Secretary of the Navy, reauthorized the construction

of the smaller of the two cruisers provided for in the act of 1882, and in addition two cruisers of about 3000 tons displacement, and one dispatch-boat, and appropriated $1,300,000 to commence their construction and procure the armament. Under the direction of the Secretary of the Navy, the Naval Advisory Board prepared general designs and published circulars giving the general features of the design of each vessel. These were submitted to prominent ship-builders for suggestions, and upon their approval by the Department, the details were prepared in the appropriate bureaus, subject to the examination and approval of the Board. The Secretary of the Navy having decided to utilize the national navy-yards only for the construction of the masts, spars, rigging, boats, stores, etc., and ordnance, advertised on May 2d, 1883, for proposals for the construction of the four vessels. Sixteen bids were received for the vessels separately, from eight different firms. Those of Mr. John Roach, of Chester, Penn., proved the lowest in each case, his total bid being $2,440,000; $774,000 less than the Board's estimates, and $315,000 less than the next lowest bidder. These great variations were due to the lack of definite knowledge of the price of the high grade of mild steel required by statute.

About the 1st of August, the detail plans of the hulls and machinery having been approved by the Board and the Department, contracts were entered into with Mr. Roach for the following vessels, viz :

Twin Screw Steam Cruiser Chicago.

Length between perpendiculars,	315 ft.
Length on water line,	325 ft.
Length over all,	334 ft. 4 in.
Depth from garboard strake to under side of spar deck,	34 ft. 9 in.
Height of gun deck port sill from load water line,	10 ft.
Height of spar deck port sill from load water line,	18 ft. 6 in.
Breadth, extreme,	48 ft. 2½ in.
Draught of water at load line, mean,	19 ft.
Displacement,	4500 tons.
Area of plain sail,	14,880 sq. ft.
Complement of men,	300
Battery, four 8-inch long breechloaders in half turrets, eight 6-inch and two 5-inch on gun deck.	
Indicated horse power,	5000
Sea speed,	14 knots.
Capacity of coal bunkers,	940 tons.

Contract price for hull, machinery and fittings, exclusive of mast, spars, rigging, sails, &c., $889,000.

The Chicago is a coal-protected steam cruiser, built of mild steel throughout and without wood sheathing, and will contain the latest improvements in naval construction and ordnance. The battery will consist of four 8-inch high-powered breechloaders, weighing about 12 tons each, mounted in projecting half-turrets on the flush spar deck, the centre of the trunnions being 20.25 ft. above water. The turrets are unarmored, and the guns fight in large open ports. The only protection for the men is afforded by shields on the guns. The train of the forward guns will be 3° across the bow to 60° abaft the beam, and similarly aft. Six 6-inch B. L. R., weighing about 4 tons each, will be mounted in broadside on the gun deck, with a train of 60° before and abaft the beam. This deck has been arranged and ports will be cut for two additional 6-in. guns on each broadside, which may be fitted if found desirable at any time. One 6-inch will be mounted in a recessed gun-deck port on each bow, with a train of from 3° across the bow to 52° abaft the beam. Two 5-inch guns in recessed ports abaft the captain's cabin complete the main battery. The weight of the 8-inch projectile is 250 lbs.; 6-inch, 100 lbs.; 5-inch, 60 lbs. There will be in addition, four 47 mm. and two 37 mm. Hotchkiss revolving cannon, mounted in fixed bullet-proof towers. Considering that these guns fire from 60 to 80 rounds per minute, and the shot from the heavier calibre can pierce the side of any unarmored vessel at 2000 yards, we obtain a conception of what a formidable element they will form in warfare. The number of probable hits from such a machine-gun battery along the water line emphasizes the great importance of minute watertight subdivision, both horizontal and vertical.

The Chicago is divided by nine complete transverse bulkheads extending to the gun deck, into ten main watertight compartments. The four amidship compartments, extending over 136 feet in length, are occupied by the machinery and boilers. An inner bottom extends throughout this space, forming a double bottom 3 ft. 6 in. deep amidships, which is divided by the vertical keel and transverse watertight frames into fourteen watertight cells.

The machinery and boilers are covered by a protective steel deck 1½ in. in thickness. The top of this deck is one foot above the load water line and is nearly flat, or has the ordinary round of the beams for about half the breadth amidships. At about 12 ft. from the side it

bends downwards, striking the side at 4 ft. below the water line. Vertical longitudinal bulkheads extend on each side of and throughout the length of the machinery and boiler compartments. The space between them and the sides of the ship will be filled with coal, giving a coal armor of 9 ft. in thickness from the water line to 8 ft. above it, and aft an average thickness of 5 ft. from the water line to 14 ft. below it. These coal bunkers, with the pockets in the boiler rooms, form thirty-four watertight compartments when the doors are shut. The machinery compartments contain the vitals of the ship, and demand all available protection. It is not expected that the deck which covers them will resist a 6-inch shot at even so small inclinations as 6° to 8°; but the protection afforded by such a deck is of great value in preventing the direct access of shot and water to the main compartments, in resisting machine gun-fire, and from the fact that entering shell will probably explode among the coal without injury to the machinery.

The magazines, shell rooms and fixed ammunition rooms are situated in the hold amidships, directly before and abaft the machinery space, only separated from the forward boiler room by the cable tanks, and from the after engine-room by a handing and light room. The flats beneath them are watertight and form a virtual double bottom extending about 40 feet before and abaft that properly so called. The deck above them is covered by protecting plating $\frac{3}{4}$ in. thick, the remainder of this deck is of steel $\frac{1}{4}$ in. thick, making a complete watertight flat. All hatches leading through it have watertight covers, and the magazine hatches are surrounded by coffer dams leading to the berth deck. Additional bulkheads of steel make other necessary divisions in the hold, and with the shaft alley bulkheads and those already mentioned divide the ship into 85 watertight compartments.

A complete system of drainage is provided for by which the total pumping power of the steam and circulating pumps, with capacity of 2500 tons per hour, can be concentrated on any main compartment. In addition to the steam pumping system, there are six continuous acting hand pumps on the berth deck which have independent suctions to each main compartment and each compartment of the double bottom; they deliver into the fire main or directly overboard as required, and can also be used for flooding any compartment or flushing the large drain pipes. A fire main extends about three-fourths of the length of the vessel amidships on the berth deck with stand

pipes to gun and spar decks, and will have cocks with hose attached at intervals on each deck; this main is supplied by one of the large steam pumps or any or all the hand pumps.

Material and Scantlings.—The Act of Congress of August 5, 1882, required these vessels to be "constructed of steel, of domestic manufacture, having as near as may be a tensile strength of not less than 60,000 lbs. to the square inch, and a ductility in eight inches of not less than 25 per centum." See Appendix I. for "Tests of Steel for Cruisers." The outside plating will weigh 23 lbs. per square foot, or be about $\frac{9}{16}$ in. in thickness; worked lap jointed, and double riveted at edges and butts to the height of the protective deck, and flush jointed, for appearance sake, from there up, the flush jointed plates being single riveted at the edges. The sheer strake will be doubled for about 250 feet amidships, and a doubling plate will be worked at the water line extending from the stem to about 70 feet from the stern. The flat keel is formed of two thicknesses of plate each 25 lbs. per square foot, the vertical keel of plate 20 lbs. per square foot, or $\frac{1}{2}$ in. thick; the continuous angles at its upper edge will be $3'' \times 3'' \times 7$ lbs. per lineal foot, those at the lower edge $3'' \times 3'' \times 8\frac{1}{2}$ lbs. The butts of the vertical keel will be double strapped and treble chain riveted. Each butt of the flat keel plates will have a butt strap of the same thickness as the plates and treble chain riveted. The stem and stern post will be of hammered steel. The watertight inner bottom will be of plating $12\frac{1}{2}$ and 10 lbs. per foot, except the shoveling flat in the wing coal bunkers, which will be 15 lbs. or $\frac{3}{8}$ in. thick.

The transverse frames formed as shown in plate II, are spaced four feet apart throughout the double bottom, and three and a half feet elsewhere. The framing throughout the double bottom is on the bracket plate system, the frames being each $5'' \times 3'' \times 10$ lbs., and the brackets $12\frac{1}{2}$ lbs. per square foot. The outer frame angle is continuous from keel to armor deck, and the reverse frame is continuous from the second longitudinal to the same height. Above the protective deck both frames continue to the spar deck. Before and abaft the double bottom the frames will be of the ordinary construction, the outer being continuous from keel to upper deck, and the inner bar from the second longitudinal up. This framing is continued to the extremities, the run having been kept sufficiently full to obtain the strength necessary to carry a protected rudder. The longitudinal frames within the double bottom are formed of continuous plates $\frac{3}{8}$ in. thick, slotted over the outer frame angle; the inner continuous angles

being $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 5$ lbs. per foot, and the outer intercostal bar $3'' \times 3'' \times 7$ lbs. The third longitudinal from the keel will form the outer boundary of the double bottom, and will be composed of intercostal plates of 15 lbs. per square foot and stapled angles $2\frac{1}{2}'' \times 2\frac{1}{2}''$ of 5 lbs. This is made carefully watertight. The fourth longitudinal from the keel stiffens the framing in the wing coal bunkers, and is continued right fore and aft. The longitudinal is also continued fore and aft as the berth deck stringer.

The main bulkheads are formed of plate $12\frac{1}{2}$ and 10 lbs. per square foot, stiffened by vertical angles $3'' \times 3'' \times 7$ lbs. each, 30 in. apart. Below the berth deck horizontal T bars will be fitted, possessing additional stiffness and serving as edge strips. It is well to notice here that as the bulkheads and inner bottom are comparatively light—mainly $\frac{1}{4}$ in. and $\frac{5}{16}$ in.—the durability of these parts will mainly depend upon the care exercised by commanding officers in keeping the ship dry, clean, and well painted. With this view, great pains will be taken to make every part accessible.

Spar Deck.—Stringers 11 ft. wide amidships of $17\frac{1}{2}$ lbs. per square foot, flush jointed, single riveted at the edges, and double at the butts. Tie plates at side of hatches.

Gun Deck.—Stringers 14 ft. wide amidships, covering the side coal bunkers, of $12\frac{1}{2}$ lbs. per square foot. Continuous ties at sides of hatches. The plating on both these decks will be reduced to 10 lbs. per square foot at the extremities.

Berth Deck.—Protective plating for 136 ft. amidships over the engines and boilers. This will be worked in two thicknesses of $\frac{3}{4}$ in. each, forming butt straps and edge strips for each other. Before and abaft protective plating there will be a stringer 36 in. wide and 15 lbs. per square foot. Watertight flats before and abaft machinery spaces, plating 10 lbs. per square foot.

It will be noticed, from the arrangement of deck plating and the comparatively heavy bottom plating, that the Chicago will have ample structural strength. In fact, it has been estimated that under the most unfavorable circumstances of the vessel resting on the crest of a wave and subjecting to hogging, that the stress on the upper deck plating will not exceed three tons per square inch.

The rudder and steering gear are completely beneath the water line. Additional protection is given to the rudder-head, false rudder-post and tiller, by a horizontal shield or flat $1\frac{1}{2}$ in. in thickness. A fighting hand wheel and the steam steering engine will be situated on the

watertight flat, to which communication can be made by telegraph from the bridges. There will also be a hand-steering wheel aft on the spar deck, and a steam-steering wheel in the pilot-house on the forward bridge. There will be two bridges, one forward of the smoke-pipes, extending over the 8-inch gun turrets. On this bridge a roomy chart-house and, probably, an armored pilot-tower will be placed. The second bridge will be over the after half turrets.

The Chicago will be bark-rigged—the area of plain sail being 14,880 square feet, or about two-thirds full sail-power. It is intended that sail shall be auxiliary, as the coal supply is ample to supply power for long voyages under steam alone. The normal coal supply is 800 tons, the bunker capacity is 940 tons, and 300 tons additional can be safely and easily stowed on the berth deck. Thus, with a total coal supply of about 1240 tons, the Chicago can steam 3000 miles at 15 knots and 6000 miles at 10–11 knots per hour.

Passing to the structure again, the bow of the vessel will be strengthened for ramming; the peak compartment being carefully subdivided by an additional bulkhead, watertight flats and breast hooks, in order to insure, as far as possible, that damage incurred in ramming shall not extend beyond the collision bulkhead.

The vessel will be ventilated by an exhaust system similar to that so successfully employed on the U. S. S. Richmond. Two large blowers situated on the berth deck draw air through large ducts extending fore and aft and with branches to all living spaces and store-rooms, and deliver into ducts leading to the open air. A separate system is used for the engine and boiler compartments. Pipes are fitted leading from the topsides to supply fresh air to the coal bunkers, and another system, delivering into the funnel casing, provides an exhaust for gases which may escape from the semi-bituminous coal to be carried.

Machinery.—The Chicago will have twin screws, actuated by two pairs of two-cylinder compound overhead beam engines, shown in plate V. Each engine, with its independent auxiliary machinery, will be placed in a separate watertight compartment 22 feet long and enclosed by the protective deck, which is 12 inches above the water line amidships, giving a height in clear between the inner bottom and the under side of beams of 15 feet 8 inches.

The high and low-pressure cylinders will be located side by side, with axes vertical, eight feet apart and respectively2 feet 1 inch and 3 feet 5 inches from the midship line, the cylinders of the forward engine being

placed on the port side. Their diameters will be 45 and 78 inches and their piston stroke 52 inches. Each cylinder will be steam-jacketed and fitted with two double-ported main slide valves, worked by means of eccentrics through arms and rock shafts, each fitted with a steam cylinder and piston to balance the weight of the valves. Cut-off valves receiving motion from the beam centres, and adjustable between the limits of $\frac{1}{8}$ and $\frac{5}{8}$ of the stroke, will be fitted to the back of each main valve. The exhaust steam from the high-pressure cylinder will pass directly to the low-pressure steam-chests; it will also be arranged with suitable pipes to exhaust the steam into the condenser and atmosphere. The low-pressure cylinders will be fitted to receive the steam directly from the boilers, and also to exhaust into the atmosphere. The condensers are to be placed outboard of the low-pressure cylinders and to rest upon them and the frames of the air and circulating pumps. They will have tinned brass tubes exposing a cooling surface of about 5000 square feet each. An independent, double-acting, combined air and circulating pump will be placed beside each condenser. Two double-acting feed pumps five inches in diameter will be worked from the cross-head on the piston of each pump.

The crank shafts for each engine will be "built up" steel forgings in two separate interchangeable sections, and secured to each other and the line shafting by couplings forged on the shafts. The line shaftings will be of steel 13 in., the after section being $13\frac{1}{2}$ in. in diameter. The outboard portion of the shaft will be supported by two hangers or A frames. The propellers will be made of steel with four adjustable blades, to have a diameter of 15 ft. 6 in., and a mean pitch of 22 ft. 6 in. The beams are to be constructed of two cast steel plates of parabolic form, about 11 feet long between extreme centres; greatest depth of beam 48 in.; the web of the plates will be $1\frac{1}{2}$ in. thick, with a perimeter 3 in. wide and 2 in. thick; the bosses for the beam centres to be 20 in. in diameter and 12 in. thick, those for the connecting rods to be 15 in. in diameter and 7 in. thick. These beams may be constructed of rolled steel plates. All the pins will be of steel. The beam pillow blocks and the frames upon which they rest will be constructed of cast steel, the body of the frames to be 16 in. wide and $1\frac{1}{2}$ in. thick, the side flanges 18 in. wide and $1\frac{1}{2}$ in. thick; one foot of each frame rests on and is firmly bolted to the crank shaft block, while the other rests on the steam-chest.

The reversing cylinders will be located between the cylinders and crank shafts, and will connect directly with the arms of the rock

shafts; the valves to be operated by floating levers from the working platform. This platform is outboard of the crank shaft and opposite the space between the cylinders.

Beam engines have long been successfully employed in paddle steamers, but only occasionally used for screw vessels. One well-known instance, however, is the Louisiana, the fastest vessel on the regular lines from New York to New Orleans. Their application to the propulsion of a twin screw protected cruiser is novel, if not unique; but their adoption is not in the nature of an experiment, and was only after careful comparison with special designs of both vertical direct acting and horizontal types. It was found impossible to get a vertical inverted cylinder engine beneath the water line, and, if used, it would certainly have exposed the vessel to vital injury from guns of small calibre. On comparison with horizontal engines, the advantage of vertical cylinders in wear and less work lost in friction, the longer stroke and connecting-rod, the easy accessibility of the working parts of the beam engine, led to its adoption. We generally find poppet valves employed on beam engines, and it has been proposed to use them on the Chicago. Their advantages of small power required to work them and definite action are undoubted; but it has been the general opinion that their success would be doubtful when used upon an engine of this size, making as many as eighty turns a minute.

In regard to the use of twin screws, it seems hardly necessary to repeat the lines of argument concerning them. There seems to be little doubt they are equally if not more efficient as propellers than single screws. A war vessel now building of over 3000 tons displacement, with single screws, is an exception, on account of the great advantage of subdivision of the power; for, if one engine is broken down, three-fourths speed can be maintained with the other. This arrangement admits of more complete watertight subdivision and more convenient stowage—the engines for each screw being entirely independent and in separate compartments, the motive power cannot be disabled by bilging a single compartment. Again, experienced engineers do not consider it safe to put the tremendous powers now used into a single engine unless they are subject to periodical and frequent overhauling, as in the case of merchant steamers. The merchant service does not use twin screws on account of their greater first cost, larger running expenses, the liability to injury alongside docks and greater space occupied; all of which are good commercial, but not good military or scientific, reasons against their

employment. It is found from experience that twin screw engines do not weigh much more than single engines of the same power. Twin screws render it possible to place the rudder and steering gear beneath the water line, and also furnish additional manœuvring power. With one screw going ahead and the other astern, a vessel can turn nearly on her own centre, though the time is slightly greater than when turning under full headway. This economy of space is, however, a great tactical advantage.

The weight of the machinery forming such an important factor in the design, the question of coal has demanded attention. It has been the custom to put into our naval vessels about fifty per cent. more grate surface for corresponding power than is customary in any national or merchant marine, the object being to use anthracite instead of soft coal, their rates of combustion being in the ratio of 1 to $1\frac{1}{2}$–2. According to an eminent authority, "the advantages of anthracite over semi-bituminous coal are freedom from dust and smoke; both important in a war vessel, but particularly the latter." The same writer goes on to demonstrate the commercial value of these qualities by saying, "They have to be paid for in the enormous excess of boiler required. So strongly marked is the inferiority of anthracite in this respect, that none of the transatlantic steamers voyaging to our ports use it for their return trips, although its cost per ton is fully one-third less [?] They prefer to pay this greater price rather than submit to the disadvantage of loss of speed or larger boiler." It is well known to naval officers that our vessels on foreign cruises never obtain or try to obtain anthracite coal after leaving home. The fact is, that the neatness and cleanliness of our fine frigates has been obtained at a tremendous sacrifice of efficiency as war vessels. The question of smoke is more a bugbear than anything else in a high speed ship; for, in the first place, the best quality of Cumberland coal makes little or no smoke with properly designed furnaces and careful firing; the soft coal used in the British and French navies is not objected to on that account. In connection with the argument that a smoky fire, lasting even a few minutes, reveals the ship's presence to the enemy, it may be well to recall the fact that the blockade-runners put their faith in free-burning coal, and with the extra speed obtained from forcing the fires escaped in full view of the blockaders. The weight saved in the weight of machinery of the Chicago by designing on the basis of soft coal amounts to more than the whole weight of the armament, or to two days' coal

supply at full power, or other things being the same it would have been impossible to carry a protective deck.

The type of boiler intended for the Chicago (see plate V) is new to the naval service, but is in successful operation in merchant steamers. There will be fourteen horizontal return-tubular boilers, designed to carry a working pressure of 100 lbs. per square inch, and constructed of steel which must conform to the "tests of steel for cruisers" prescribed by the Naval Advisory Board (see Appendix). They will be contained in two separate watertight compartments. The fire-rooms run fore and aft, and are to be 11 feet wide, except between the two forward boilers, which are canted inboard. There are to be two fixed smoke-pipes, each connecting with an up-take common to the boilers of each compartment. Each boiler will be 9 feet in external diameter, 9 ft. 10 in. in length on the bottom, and set inclining downwards from front to back, over a single furnace below the shell, being supported by girders of boiler plate lined with fire-brick. Each furnace is to have a grate about 7 ft. 8 in. wide and 7 ft. 6 in. long, making about $57\frac{1}{3}$ square feet, and aggregating 802 square feet in the fourteen boilers. The shells will be $\frac{5}{8}$ in. and the heads $\frac{3}{4}$ in. and $\frac{5}{8}$ in. The tubes will be of lap-welded iron. There is to be a steam drum in each smoke-pipe, concentric with it, and 9 feet in diameter, 9 feet long, $\frac{7}{8}$ in. thick in shell; it is to have eight 18 in. and four 15 in. lap-welded flues passing through it.

The fire-rooms will be made airtight, and will be fitted with two large blowers each, which it is expected will be capable of maintaining a pressure of about an inch of water above the atmosphere. By this means the rate of combustion can be readily doubled when great speed is required for a short period.

The following advantages are claimed for these boilers over cylindrical marine boilers of ordinary construction having the same amount of grate and heating surface, viz. they occupy less space in the vessel, as a boiler 9 feet in diameter contains nearly the same grate surface as an ordinary boiler 12 feet in diameter. They are stronger and particularly well fitted for high pressures, as with the same thickness of shell the strength is in the inverse proportion of the diameter; and the large furnace flues, the weakest and least reliable portion of the ordinary boiler, are wanting here. The flat stayed surfaces, which are likewise a source of weakness, are of relatively small extent here. As the steam is generated to a great extent at the very bottom of the boiler and escapes readily from the furnace-crown, no mass of dead

water can exist in it; the temperatures at top and bottom are nearly equal, and consequently the boiler is not liable to the destructive strains due to these differences of temperature arising with internal furnaces. The boilers are accessible for cleaning and repairs; the furnace-crown can be scaled with ease, as there are no seams or rivets in it. They are efficient steam generators and well adapted to high rates of combustion and forced draught, as the furnace is larger and higher than can be obtained in an ordinary cylindrical boiler. In consequence of the brick lining a high furnace temperature is maintained, favoring not only a perfect combustion of fuel, but increasing the efficiency of the heating surfaces.

The weight of the boiler, with its supports, furnaces, fittings, and water, is about the same as an ordinary boiler, but the amount of water carried is much less, and hence permits steam to be raised much quicker. Moreover, these boilers are cheaper to construct and keep in repair than ordinary boilers, on account of the simplicity of the casings and linings of the furnaces, which can be readily removed.

The question of the speed of these cruisers is one of the greatest importance and interest; but, on the other hand, an exceedingly delicate one to consider. The most, or, we may say, the only, satisfactory method of approaching it is by comparison with reliable trials and careful experiments upon similar vessels. The absence of any such data in the Navy makes it necessary to be very cautious. Ample power has been provided to obtain the designed speed, and if the machinery proves efficient and the screws suitable, it will not be a surprise if the Chicago makes nearly sixteen knots on the measured mile. When these vessels are finished and elaborate trials made of their speed and the efficiency of their machinery upon a measured distance, which is now the recognized standard of performance, then it will be possible to more carefully analyze the design, and, by giving to one part and taking from another, endeavor to improve in vessels which may follow. With this view the contracts have been carefully drawn, making it necessary to weigh each piece of material and every article or fitting that goes on board, both for the hull and machinery. In case of the Chicago the contractors guarantee, under penalty, that the weight of the machinery shall not exceed 937 tons.

Single Screw Steam Cruisers Boston and Atlanta.

Length between perpendiculars,	270 ft.
Length on water line,	276
Length over all,	283
Depth from garboard strake to under side of superstructure deck,	34
Height of main deck port sill from load water line,	11
Free board at extremities of superstructure,	9
Breadth—extreme,	42
Draught at load water line—mean,	16 ft. 10 in.
Displacement at water line,	3000 tons.
Area of plain sail,	10,400 sq. ft.
Complement of men,	230
Battery, four 8-inch and six 6-inch B. L. R.	
Indicated horse power,	3500
Sea speed,	13 knots.
Capacity of coal bunkers,	580 tons.
Contract price for hull, machinery and fittings, exclusive of masts, spars, rigging, sails, boats, &c.	$618,000

The arrangement of the battery of the Boston and Atlanta, shown on plate VI, is certainly formidable and warlike in appearance, and the guns are mounted to command such an extensive train, or sweep of the horizon, that one of these vessels might prove no mean antagonist for a frigate of the Chicago class.

In vessels of the Boston class it is usual to have an open deck battery and a poop and topgallant forecastle, but here we may say that the poop and forecastle have been moved to the centre of the ship, forming a central superstructure, leaving the extremities clear and unobstructed.

Outside the forward port angle, and the after starboard angle of the superstructure an 8-inch long rifled gun will be mounted in a barbette about 3 feet high, built of 2 in. steel plates. The forward gun has a train from 40° abaft the beam on the port side sweeping the whole deck forward to 30° abaft the beam on the starboard side; similarly for the after gun. Within the superstructure six 6-inch B. L. R.'s will be mounted; two, on each broadside, with a train of 60° before and abaft the beam; one, forward in the starboard angle of the superstructure, may fight either through a forward or a broadside port, giving a total train of from 20° across the bow to 60° abaft the beam. The remaining gun is similarly mounted on the port side aft.

Comparing this disposition of the guns with that of an open deck battery with the two 8-inch and two 6-inch in side half turrets, we have gained in strength of fire on each broadside by one 8-inch gun; the train of the 6-inch gun at the extremities has been much increased, besides the advantage of giving these guns a clean sweep across the bow and stern. The crews of the 6-inch guns are protected from the fire of machine guns from an enemy's tops, and the guns cannot be fouled or disabled by falling spars and rigging. The manipulation of the guns is much simplified, and the service of ammunition much safer and more convenient, as the standing and running rigging leads to the superstructure deck. The side, at about the level of this deck, tumbles sharply home, plate VII, allowing convenient place for stowing the boats and manipulating the boat gear, which usually forms an obstruction to the fire of an open deck battery. The 8-inch guns will carry an armored mantlet as protection against machine gun fire.

The extremities of these vessels will not, of course, be so dry in heavy weather as if they had a forecastle and poop, but we should remember that every part of the deck is from 9 to 10 feet above the load water line, and that the men, instead of being exposed on an open deck or confined to a close berth deck, will have dry, airy quarters within the superstructure, which has a height seven feet in the clear beneath the beams. A bulkhead extends across the main deck abaft the after broadside guns. Abaft this on the starboard side is the captain's cabin. The space within the superstructure forward of this is devoted to the berthing of the men. It will be fitted with mess tables, seats, and chests for the crew. In all the cruisers particular attention has been paid to providing proper quarters and arrangements for the comfort and cleanliness of the men. The old-fashioned head will be replaced by the latest improvements; bathrooms and washrooms will be fitted and supplied with water, and a separate washroom will be fitted on the berth deck at the exit from the fireroom for the use of the firemen. The officers' quarters are shown on the plan of the berth deck, the aftermost compartment being used as a bathroom.

Beneath the main deck the internal arrangements of the Boston and Atlanta are very similar to those beneath the gun deck of the Chicago. There are eight complete transverse bulkheads extending to the main deck, dividing the ship into nine main compartments, one less than the Chicago, as the Boston has a single screw and the engines occupy only one compartment.

The machinery spaces, extending over a length of 100 feet, are enclosed by a protective steel deck $1\frac{1}{2}$ in. thick. Special structural arrangements have been made in order to so place this deck with reference to the water line as to afford the maximum protection to the buoyancy. The small draught of water of the Boston, two feet less than that of the Chicago, the larger diameter and length of the boilers, and the rapidly decreasing breadth of the vessel before and abaft the midship section, make it necessary to dispense with beams beneath the deck. The deck is stiffened at the sides, as shown on the midship section, by the transverse frames in the lower coal bunkers, the brackets in the upper, the fore and aft coal bunker bulkheads; and amidships by deep I girders. A light steel deck $\frac{1}{4}$ in. thick may be fitted over these girders in addition to the planking. One of the spaces marked A, between the flat and the deck proper, on each side will be utilized as a ventilating deck to lead air from the extremities of the vessel to the blowers amidships.

It may be allowable here to make a slight digression in reference to the draught of water. There is a general opinion among naval officers and others that small draught is necessary and desirable for American men-of-war in order to permit them to enter our ports. The advantages of large draught are many and important; it is the most valuable and economical direction in which to increase the dimensions of ships, and particularly of war vessels, because the increased depth beneath the water line renders possible a more efficient disposition of, and greater protection to, the machinery, and greater immersion of the screws. It has been shown that it enables us to obtain forms of less resistance, thus favoring economical propulsion and high speeds. Again, deep draught tends to produce, what is of great importance to gunners, a steady ship in a seaway. In view of these manifest advantages it seems advisable to draw attention to the fact that the Chicago, drawing 20 feet 6 inches extreme draught, can with safety enter thirty-two ports on the Atlantic coast; the Boston and Atlanta, drawing 18 feet 6 inches aft, can enter only six ports from which the Chicago is debarred, namely, New Bedford, Fall River, New Haven, Washington, Annapolis and Tampa. If the Chicago's draught had been two feet greater she would be debarred from only two ports among the thirty-two, namely, Marblehead and Vineyard Haven, showing that an extreme draught of 22 feet might be adopted as safe, convenient and advantageous for cruising vessels.

To return to the internal arrangements, an inner bottom extends

throughout the length of the machinery spaces, forming a watertight double bottom containing twelve watertight cells. Longitudinal bulkheads extend, as in the Chicago, on each side throughout the machinery space, forming side coal bunkers, and affording a coal armor of about 8 feet in thickness above the water line, and an average thickness of about 5 feet below it. The arrangement of watertight flats and bulkheads forward is similar to that of the Chicago, but aft it is not so convenient, as the best part of the stowage beneath the flat is taken up by the shaft alley. Altogether the Boston is divided into seventy-three watertight compartments. Great care has been exercised in arranging openings to these compartments that they may really be watertight, that is, the watertight doors have been made readily accessible, and arranged for manipulation from below or from the main deck. The systems of drainage and ventilation will be similar to and in every respect as complete as those in the Chicago. The total pumping power is 2000 tons per hour.

All the cruisers will be fitted with bilge keels. As doubts are frequently expressed as to their usefulness in limiting the rolling of ships, the following experiment may prove interesting. It was made by Mr. Froude upon the Greyhound, a vessel of 1100 tons displacement, with bilge keels, and the Perseus, a sister ship, without them; both vessels having been carefully trimmed to the same natural period.* Mr. Froude says: "Three times we had them outside the breakwater at Plymouth in a tolerably rough sea. We could not, indeed, find a long rolling sea that would make the ships roll very regularly; but the upshot was that upon all occasions the Greyhound rolled just half as much as the Perseus rolled. The biggest roll we got out of the Perseus was about 23°, and the biggest roll we got out of the Greyhound was $11\frac{1}{2}°$, and the periods were just the same. The addition of bilge keels does not materially augment the period, but it augments immensely the destructive power of the surrounding water in killing the oscillation that the wave originates." In his evidence before the Committee on Designs of Ships of War (1871), Mr. Froude gave the following table of results of many observations upon the rolling in still water of a large model of the Devastation. The model was $\frac{1}{36}$ the dimension of the ship and loaded to give the corresponding displacement, centre of gravity and distribution of weight, as in the ship itself.

* Transactions Inst. Naval Architects, 1874.

Conditions.	No. of double rolls with 8½° initial angle.	Period of double roll.	No. of double rolls with 24½° initial angle.	Period of double roll.
(1) No bilge piece,	31½	1.77″	29	1.78″
(2) Single 21 in. bilge piece on each side,	12½	1.90	8½	1.90
(3) Single 3 ft. " " " "	8	1.90	6¾	1.90
(4) Pair of 3 ft. " pieces " "	5¾	1.95 1.90	5½	2.00 1.85
(5) Single 6 ft. " piece " "	4	2.00 1.98	3½	2.00 1.75

The advantages obtained by the use of bilge keels are clearly demonstrated by these experiments, and are abundantly confirmed in practice. The increase of resistance due to their use is very small and hardly to be detected in its effect upon the speed.

The structural arrangements of the Boston and Atlanta are similar, with the exception of the protective deck, to those of the Chicago. There is very little change in the *scantlings*, which are as follows for the principal parts, viz.:

Outside plating, including flat keel plates, 20 lbs. per sq. foot. Vertical keel plate, 17½ lbs. per sq. foot, 40 inches deep. The stem and stern posts will be of hammered scrap steel. Inner bottom, 10½ lbs. per sq. foot, except at centre and on shoveling flat, where it will be 15 lbs. The transverse frames throughout the double bottom to be spaced 4 feet from centre to centre, and before and abaft, 3 feet 6 inches apart.

The frame angles will be 5″ × 3″ × 10 lbs. per foot, and the reverse angles 4″ × 3″ × 8 lbs. per foot, except at watertight frames and bulkheads, where the angles attaching them to the outer skin, keel, &c., will be 3″ × 3″ × 7 lbs. per foot. The frames and brackets will be cut short of the skin plating and secured to keel angle longitudinals by angles 2½″ × 2½″ × 4½ lbs. per foot. Reverse frames will be worked in short lengths between the keel and second longitudinal, but continuous from the latter to the protective deck and longitudinal coal bunker bulkhead. Forward and abaft the double bottom, the transverse frames will be composed of frame and reverse angles, both as within double bottom, and floor plates 12½ lbs. per sq. foot. Both angles will be continuous from the keel to the superstructure deck, except in wake of continuous longitudinals where the reverse bar will be worked in short lengths.

The first and second longitudinals from the keel are continuous and formed of plates 16 to 20 feet in length, weighing 12½ lbs. per sq. foot. The outer and inner angles are $3'' \times 3'' \times 7$ lbs. per foot and $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 5$ lbs. per foot. The other longitudinals are fitted as shown on the midship section.

Decks.

Superstructure deck.—There is no plating inside the hammock netting except a tie plate alongside the hatches.

Main deck.—Within the superstructure there will be a continuous stringer 33 inches broad and of 15 lbs. per sq. foot. The remainder of the deck is completely plated with steel weighing 12½ lbs. per sq. foot.

Berth deck.—The protective plating over the engines and boilers will be made up of two thicknesses, of 30 lbs. per sq. foot each, and armored shields or bars will be fitted in all hatchways. Before and abaft the protective deck there will be a stringer 30 inches wide and weighing 15 pounds per sq. foot. The watertight platforms or orlop deck will have a complete steel deck 10 lbs. per sq. foot.

The rig of the Boston and Atlanta will be that of a brig to topgallant sails, making a spread of 10,400 sq. feet of plain sail. With a fair wind this disposition of the sail power will be more efficient than a bark rig, because in the latter the main course can seldom be set on account of the smoke pipe. In order that the fire of the forward guns should be unobstructed and the ram always ready for use head booms will be dispensed with.

The coal bunkers of the Boston and Atlanta have a capacity of 580 tons, but nearly 200 tons additional can be safely taken on board when necessary, thus giving an endurance of 2500 miles at full speed and 5300 miles at about 10 knots an hour.

Machinery.—The motive power of the Boston will be furnished by a three-cylinder, compound, horizontal, back acting engine of 3500 indicated horse-power. Plates IX and X show transverse sections of the machinery through high- and low-pressure cylinders, with the principal working parts.

The engine is to have one high-pressure cylinder of 54 in. diameter, and two low-pressure cylinders of 74 in. diameter, and each will have a piston stroke of 42 in.; the cylinders will be placed on the starboard side of the ship with their axes parallel, and 9 ft. 6 in.

apart. Each cylinder will be steam jacketed and provided with two main valves and two expansion valves, the latter will be adjustable while the engine is in motion to cut off between the limits of one-eighth and five-eighths of the stroke of the piston. The two main valves will have separate valve stems and connections, but, of course, are worked simultaneously from the same cross-head. By making the valve in two parts we gain in quality and workmanship and greater facility of examination. These valves are to be worked by means of eccentrics and Stephenson links acting through arms and rock shafts. There is a joint in the suspending-rod of the main link, which allows slight play in order to prevent any vibration being carried to the reversing gear. Much space is saved by making the eccentrics large and fitting them over the crank-shaft couplings. A vibrating beam formed of two straps of wrought iron and two sets of well proportioned gibs, keys and brasses, couples the link-block with the rock-shaft arm pin. The further end of this vibrating beam is hung from a radius bar, which is so adjusted that it regulates the motion of the link-block to correspond with that of the link, so that there will be little, if any, relative motion. The expansion valves are to be operated by separate eccentrics. The high-pressure exhaust will connect with the low-pressure cylinders, so as to pass the steam direct to the steam-chests; it will also be arranged to discharge direct into the condensers; and the low-pressure steam chests will be fitted with the requisite pipes for admitting the steam direct from the boilers or for exhausting the steam direct into the atmosphere.

The high-pressure piston will have one piston rod secured to a cross-tail, which will be coupled by four side rods with two other side rods to the cross-head. The low-pressure pistons are to have two rods coupled directly to the cross-heads; the latter are to be mounted on sleds, which are to run in troughs recessed in the pump chests. The connecting rods will be made with caps, secured by steel bolts.

The crank shaft is to be made in three separate interchangeable sections, and secured to each other and the line shafting by couplings forged on the shafts. The cranks for the low-pressure cylinders to be placed at an angle of 90° to each other, and that for the high-pressure cylinder to be set between the others and at angles of 135° from them. The shaft will be of steel, and 16 inches in diameter at the main journals. The arrangement of the pillow blocks of these journals is novel, and worthy of attention. Each pillow block will be made with a cast-iron pedestal, and two wrought-iron caps and

wrought-iron and composition key-chocks above and below the brasses. By means of these and the stay rods, which take the place of the ordinary cast-iron framing, the brasses may be accurately adjusted in any direction, or readily removed.

There are to be two air and two circulating pumps, one of each coupled together and placed directly opposite the low-pressure cylinders; the pump chests will form supports for the condensers. The pumps will be horizontal, double-acting, and arranged to work independently or in connection with the main engine. Each couple, when working independently, will be operated through arms and a rock shaft by a horizontal direct-acting engine placed opposite the high-pressure cylinder. It will also be possible to make such connections that the circulating pumps shall be independent and the air pumps run by the main engine. There will be two condensers, with a total cooling surface of 8000 square feet.

The platform, with the gear for working the engine, will be placed between the condensers above the cross-head of the high-pressure cylinder; there will be suitable and convenient approaches to it from the deck, quarters and lower platform leading to the fire room and shaft alley.

The screw will be made of steel, and will have a diameter of 17 feet and a mean pitch of 20 feet, with four adjustable blades.

There are to be eight horizontal return tubular steel boilers, shown in plate XI. They will be placed forward of the engines, four on each side of the vessel, divided into two groups by an athwartship watertight bulkhead. There will be two standing smoke pipes, each connecting with an uptake common to four boilers. Each boiler is to be 11 ft. 8 in. in external diameter, and 9 ft. 9 in. long, and to have two cylindrical furnaces 43 in. in internal diameter. The furnaces will be of corrugated steel, if obtainable. Each furnace will have a grate surface of 25 square feet, aggregating 400 square feet in the eight boilers.

The boiler fittings are as usual in the service, except that the casting to contain the stop and safety valves will be made in one, thus necessitating but one opening in the boiler. The feed check valve is very conveniently arranged between two stop valves, so that it can be readily examined at any time.

It is the intention to utilize the advantages of forced draught and closed fire rooms, by which the power can be increased fifty per cent. for short periods. With this view there will be two blowers in each fire room, each capable of supplying 12,000 cubic feet of air per

minute. Great care will be taken to make the fire rooms airtight. Recent experiments have shown that, with air pressure in the fire room of an inch to an inch and a-half of water above the atmosphere, that 30 to 40 pounds of soft coal could be burned per square foot of grate per hour, giving from 13 to 16 I. H. P. per square foot of grate surface. There is nothing, however, particularly new in the employment of airtight fire rooms,* except in its use on such a large scale.

U. S. Dispatch Boat Dolphin.

Length between perpendiculars, ...	240 feet.
Length, extreme, ...	256.5
Breadth, moulded, ...	31.85
" extreme, ...	32
Depth from top of floors to top of main deck beams, .	18.25
" " base line to " " .	20.07
Top of main deck at side above load water-line, . . .	6.28
Mean draught, ...	14.25
Displacement at mean draught, ...	1485 tons.
Area of plain sail, ...	
Complement of men, ...	80
Battery—One 6-inch pivot, four revolving cannon.	
Indicated horse power, ...	2300
Speed, ...	15 knots.
Capacity of coal bunkers, ...	310 tons.
Contract price for hull, machinery and fittings exclusive of masts, spars, rigging, sails, boats, &c., ...	$315,000

* An engineer of large experience writes me as follows: "The first airtight fire-room built of iron plates and really airtight that I can recall was on the steamboat John Stevens, the hull built of iron at Hoboken by the Stevens and engined by the Morgan Iron Works, about 1847. The boilers and appurtenances were built at Hoboken. Robt. L. Stevens was the owner and designing engineer. But airtight firerooms were in successful use before this date; I think one or more boats were so fitted by Mr. Robt. L. Stevens two or three years before this. It was found that the airtight arrangement was better suited to boilers using soft or bituminous coal; and in 1850 two very fine boats, the Northern Indiana and Southern Michigan, employed on Lake Erie, were so fitted by the Morgan Iron Works; the whole of the fire-rooms were enclosed in $\frac{3}{16}$ iron, the blowers discharging through the top. Between 1850 and 1860 airtight fire-rooms were fitted to all the first-class steamers on the lakes, but in New York waters the blast was mostly applied under the grate bars, the coal used being anthracite. The boilers being placed on the guards were not so easily fitted with airtight fire-rooms, whereas on the lakes the frequent very rough water necessitated placing the boilers in the hold."—Ed.

The Dolphin, being intended for a dispatch vessel, capable of furnishing rapid communication from the seat of government to any point on the coast or the West India islands, or in event of the existence of a United States squadron, to act as fleet dispatch boat or flag-ship, the governing condition in the design has been high speed capable of being maintained for several days.

In order to obtain the most efficient and durable type of machinery, it was necessary to abandon any attempt at protection; thus we see from the drawings that the vessel is throughout of the ordinary merchant ship construction.

The Dolphin has a flush open spar deck without poop-cabin or forecastle; there will be a small central deck house near the cabin gangway and another around the boiler and engine hatches, otherwise the deck is uninterrupted fore and aft.

The armament is very light, consisting of one 6-inch B. L. R. mounted with a shifting pivot just forward of the fore-bridge, and four 47 mm. Hotchkiss revolving cannon mounted at the extremities of each bridge in fixed armored towers.

The Dolphin will be rigged as a three-masted schooner, the spars will be small and light, and there will be no head-gear; so that there will be nothing in the outward form of the vessel to prevent her from being fast and seaworthy.

The structural arrangements are those in practice in the construction of merchant vessels, except that unusual care has been taken to divide the hull into six watertight compartments by transverse bulkheads extending to the upper deck, and more than customary longitudinal strength is provided for. The bow is slightly ram-shaped and is made specially strong.

The principal *scantlings and details* of construction are as follows: The vertical middle line keel will be 20 lbs. per sq. foot. The side bars will be 9 inches wide and $22\frac{1}{2}$ lbs. per sq. foot. The stem will be of best quality of hammered iron and 7 in. by $2\frac{1}{2}$ in., except at the heel, where it is scarfed to the side-bar keels. The stern frame will be an iron forging of section about 10 in. by $41\frac{1}{4}$ in.

The transverse frames are to be spaced 22 inches apart and be made up of a frame angle $4'' \times 3'' \times 9$ lbs., reverse, an inner frame angle $3'' \times 2\frac{1}{2}'' \times 6$ lbs., both continuous from keel to main deck; and floor plates of $12\frac{1}{2}$ lbs. per sq. foot and 18 inches deep amidships.

The flat sides or keelson plates on each side of and fitting closely against the vertical keel plate will be 12 in. wide and 15 lbs. per sq.

foot. The continuous angles at the top of the keel will be $5'' \times 3'' \times$ 10 lbs. per lineal foot.

The first longitudinal from the keel is composed of an intercostal plate of 15 lbs. per sq. foot, extending 5 in. within the reverse bars, outer intercostal angles $3'' \times 2\frac{1}{2}'' \times 6$ lbs. per lineal foot, and inner continuous angles each $5'' \times 3'' \times 10$ lbs. The second longitudinal has an intercostal plate of $12\frac{1}{2}$ lbs. per sq. foot, outer angle $3'' \times 2\frac{1}{2}'' \times 6$ lbs. and inner continuous angles $5'' \times 3'' \times 10$ lbs. The bilge stringer is simply composed of two continuous angles, each $5'' \times 3'' \times 10$ lbs. per lineal foot.

The outside plating will be $17\frac{1}{2}$ lbs. per sq. foot. This will be reduced to 15 lbs. at the extremities. The garboard strakes will be 25 lbs. per sq. foot, tapering to 20 lbs. The plating will be worked lap-jointed to within about two feet of the load water line and flush jointed above this height.

The plating and stringers on the main deck in wake of the engine and boiler hatches will be 15 lbs. per sq. foot; forward and abaft of these the plating will be reduced to 10 lbs. The berth deck stringer will be about 30 in. wide and of $12\frac{1}{2}$ lbs. per sq. foot.

The watertight flats forward and abaft of the machinery spaces will be formed of plates 10 lbs. per sq. foot jogged over the frames and attached to the plating by stapled angles $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 5$ lbs. per lineal foot.

The bulkheads will be of the usual scantlings.

The Dolphin will have a steam steering engine, artificial ventilation, and will be lighted throughout by electric light and fitted with electric search lights, head lights, &c.

Machinery.—The Dolphin will have a single screw, actuated by a two-cylinder, compound, vertical, direct acting engine of 2300 indicated horse power.

The engine is to have one high-pressure cylinder of 42 in. diameter, and one low-pressure cylinder of 78 in. diameter, having 48 in. stroke of piston. The cylinders are to be placed directly over the crank shaft; each cylinder being supported by two wrought-iron columns, which are secured to the engine bed-plate, and by two cast-iron brackets, which form at the same time the cross-head guides and are secured to the condenser.

Each cylinder is to be made with a double shell, inclosing, in the case of the high-pressure cylinder, the receiver, and, in the case of the low-pressure cylinder, the steam-passage leading from the receiver

to the steam chest on one side, and the exhaust-passage leading directly to the condenser on the other side. The total capacity of the receiver is to be about three and a half times the capacity of the high-pressure cylinder. Each cylinder will have an inner wearing cylinder cast separately, which, when secured in place, is to be surrounded by a jacket space to be filled with steam from the boilers.

The valve chests are to be placed on the forward side of the high-pressure cylinder and on the after side of the low-pressure cylinder.

Each cylinder will have a main slide-valve and a cut-off valve. The main slide-valves will be double ported, and worked by means of eccentrics and links coupled directly to the valve stems. The weight of each valve is to be counterbalanced by a piston working in a cylinder placed on the top of the steam-chest.

The cut-off valves are to slide on the back of the main slide-valves and to be adjustable, while the engine is in motion, to cut off between the limits of $\frac{1}{4}$ and $\frac{5}{8}$ of the stroke of piston of the high-pressure cylinder, and of $\frac{1}{3}$ and $\frac{5}{8}$ of the stroke of piston of the low-pressure cylinder. They are to be operated by separate eccentrics coupled directly to the stems.

Each cylinder is to have one piston-rod, at the lower end of which the cross-head journal and the gibs for the cross-head guides are fitted. The crank shaft is to be "built up" and to have two cranks at right angles to each other; the forward or high-pressure cylinder crank being the leading one. Counter-balances are to be forged on the cranks. The crank-shaft is to be mounted on four journals having an aggregate length of 84 inches, and it is to be connected with the line-shafting by a disengaging coupling.

The crank-shaft pillow-blocks are to be made in one casting, forming the bed-plate of the engine, to which the columns supporting the cylinders and the brackets supporting the condenser are to be secured, and which is to be bolted directly to the engine frames forming a part of the hull of the vessel.

There is to be one surface condenser having an aggregate cooling surface of 4500 sq. feet. The tubes are to be placed athwartships and so arranged as to be readily withdrawn and replaced. The refrigerating water, entering on the starboard side of the vessel, is to pass through the lower half and return through the upper half of the tubes, to be discharged through the outboard delivery valve on the starboard side of the vessel. The condenser is to be supported at each end by two brackets secured to the engine bed-plate.

The condenser is to be placed at the centre of engines below the cylinders, at such a height as to leave the centre main bearings accessible for examination and adjustment, and allow the shaft to be removed. To each side of the condenser are secured the brackets which support the cylinders.

The air-pump, circulating-pump, and feed-pumps are to be independent of the main engines. There is to be one horizontal double-acting air-pump, and one horizontal double-acting circulating-pump, both worked directly from the piston of a steam cylinder placed between the two pumps. The circulating-pump will be capable of discharging 3300 gallons of water. There are to be two single-acting feed-pumps, secured to the sides of the steam cylinder, and worked from the cross-head of the circulating-pump. These pumps are to be placed in a fore-and-aft direction on the starboard side of the vessel, leaving a passage-way between them and the main engines. There are to be two bilge-pumps worked by an eccentric placed on the crank-shaft directly abaft the after main bearing. The bilge-pumps are to be single-acting plunger pumps, so arranged as to be thrown readily in and out of gear while the engine is in motion; they are to discharge the water into an outboard-delivery valve chamber on the port side of the vessel.

The steam reversing gear is to be placed on the port side of the engines. It is to consist of a steam cylinder bolted to the side of the condenser, the piston of which is to act by means of a link upon an arm of the reversing shaft, which is connected by means of arms and suspension rods with the links of the main slide-valves. The valve of the starting cylinder is to be operated by a hand lever from the platform on the starboard side of the engine.

There is to be a gallery running all around the engines on a level with the berth deck. The various valves, levers, and gears for working, regulating, and adjusting the main engines are to be operated from this gallery on the starboard side. There is also to be an upper gallery on a level with the spar deck.

The screw propeller is to have four adjustable blades, a diameter of 14 ft. 3 in. and a mean pitch of 21 ft. 4 in.

The boilers are to be cylindrical, braced for a working pressure of 100 lbs. per square inch above the atmosphere. They are to have an aggregate grate surface of 270 sq. feet and an aggregate water-heating surface of about 6600 sq. feet. They are to have internal cylindrical furnaces and horizontal fire tubes returning above the furnaces. Each

furnace is to have separate back and front connections, the latter being provided with a damper.

There will be two single-end and two double-end boilers. The single-end boilers will have a diameter of 11 ft. and a length of 9 ft. 6 in. and contain two furnaces each. The double-end boilers will have a diameter of 11 ft. and a length of 18 ft. 3 in. and contain four furnaces each. The boilers will be placed with their longitudinal axes in the fore-and-aft direction of the vessel, the single-end boilers aft fronting the double-end boilers, with a fire-room 9 ft. 6 in. long between them. At the forward end of the double-end boilers there will be a fire-room 9 ft. long. On the starboard side there will be a passage way between the two fire-rooms and the engine-room.

There will be a vertical steam-drum 7 ft. 6 in. in diameter and 8 ft. 6 in. high, traversed by six flues 18 inches in diameter, and surrounded by the uptake.

The smoke-pipe will be stationary, 7 ft. 3 in. in diameter and 60 feet high above the level of the grates.

Provision is to be made for closing the fire-room hatches and other openings sufficiently tight to maintain an air-pressure equivalent to a head of water of one inch in the fire-rooms.

There will be two blowers in the after fire-room drawing the air directly from the engine-room and from a duct leading to the after part of the berth-deck, respectively; and one blower in the forward fire-room, taking the air from the forward part of the berth-deck. Each blower is to be capable of discharging 12,000 cubic feet of air per minute under a head of one inch of water at the discharge opening. The air is to be delivered directly into the fire-room. Each blower is to be driven by a separate direct-acting engine coupled to the shaft of the fan.

There is to be one horizontal steam pump, having a water piston 6 inches in diameter and 12 inches stroke, placed in the after fire-room on the port side. This pump is to be fitted for feeding and pumping out the boilers and for fire apparatus.

There is to be a distiller of 2000 gallons capacity per day, with tank, filter, and separate steam-pump, placed on a platform in the forward fire-room.

There will be two horizontal steam-pumps, each capable of delivering 1000 gallons of water per minute, connected for pumping out the watertight compartments, and also connected with sea-valves and fire apparatus. One of these pumps is to be placed on a platform in

the forward fire-room, and the other is to be placed at the after end of engine-room on the port side.

There is to be an ash-hoisting engine fitted for each fire-room, and suitable arrangements are to be made for dumping the ashes on the spar-deck.

Two steam syphon-pumps with bilge connections are to be fitted, one in engine-room and one in after fire-room.

Through the courtesy of the Office of Naval Intelligence I am enabled to append to this paper a list of war vessels (see Appendix II) building at the present day, which shows that by far the larger part of the money employed in shipbuilding for war purposes is devoted to the construction of ironclads. There is no doubt that by adding to our navy more of the classes of *cruisers* just laid down and some of about 1500 tons displacement, we shall supply the most pressing need of the department; but it should not be forgotten that in order to take rank as a naval power, or to hold the sea against a naval power of fourth rank, for instance one of the South American governments, we must have *armored* seagoing vessels. By adding to our service unarmored vessels much larger than the Chicago, and even of tremendous speed, of which the advantage is in great measure fictitious, we should increase the expense of maintenance of the navy as much as by the addition of armored vessels of moderate size, but would not add to the naval power in anything like the same proportion.

It would have been eminently more satisfactory to the writer to be able to indulge in the more intelligible and careful discussion of many points not here mentioned, possible only in describing finished vessels. It has been the endeavor to present briefly such a description as the general interest of the public and naval officers demands in what is sincerely hoped to be a beginning of the reconstruction of the cruising fleet of the navy. During so long a period of inaction we have in great measure wasted the experience and prestige gained during the war. Opponents of naval expenditure in the direction of progress have always argued that when the opportunity or emergency arrived we should have profited by the experience and enormous expenditures of foreigners, but they are as ready when the time comes to allege "servile imitation" and decay of Yankee ingenuity, forgetful that this same fertility of invention for which the country is in many arts so distinguished, is the result of great

demand, great production and resources. For instance, our excellence in wood-working machinery is not the result of spontaneous genius, but of the abundance of wood and its extensive use in thousands of various forms and devices. No doubt it is high time that we gained some experience for ourselves, for it can hardly be supposed that our officers can maintain the high state of efficiency claimed for them, by service in a fleet which is in every respect twenty-five years behind the times. However, it is confidently expected that through the cautious but sure progress of our ordnance officers in powder and guns, and the care which the department has been enabled, through the wisdom of Congress, to give to these designs, that the vessels will prove apposite to the needs of the service and at the same time compare favorably with others.

APPENDIX I.

TESTS OF STEEL FOR CRUISERS.

NAVY DEPARTMENT,
NAVAL ADVISORY BOARD, *June* 18, 1883.

The following rules are prescribed in order to insure the fulfilment of the clause of the act of Congress of August 5th, 1882. "Such vessels . . . to be constructed of steel, of domestic manufacture, having as near as may be a tensile strength of not less than sixty thousand pounds to the square inch, and a ductility in eight inches of not less than twenty-five per centum:"

I. All ship-plates, beams, angles, rivets, bolts, boiler-plates and stays, to be inspected and tested at the place of manufacture by a Naval Inspector of Material, and to be passed by him, subject to restrictions hereinafter mentioned, before acceptance by the shipbuilders, whether government or private, for incorporation into said vessels.

II. Every plate, beam, and angle, supplied for these vessels, to be clearly and indelibly stamped in two places, and with two separate brands: 1st. With that of the maker, which shall distinguish the name of the manufactory or company. 2d. With the regulation brand of the Naval Inspector of Material. The latter not to be stamped upon any of the above-mentioned material until it shall have passed the required inspection and tests, have been accepted by the Inspector, and have been stamped with the maker's brand.

In case of small articles passed in bulk, the above-mentioned brands shall be applied to the boxing or packing material of the objects.

No steel material to be received at the building yards for incorporation into the vessels except it bear, either upon its surface or that of its packing, both of these brands as evidence that it has passed the necessary government inspection.

SHIP-PLATES.

III. In every lot of 20 plates test pieces to be cut from two plates taken at random; two test pieces being cut from each plate, one in the direction of the rolling, and one at right angles to it, shaped according to the annexed sketch. These test pieces shall in no case be annealed.

The test pieces to be submitted to a direct tensile stress until they break, and in a machine of approved character.

The initial stress to be as near the elastic limit as possible; which limit is to be carefully determined by the Inspector in a special series of tests. The first load to be kept in continuous action for five minutes. Additional loads to be then added at intervals of time as nearly as possible equal, and separated by half a minute; the loads to produce a strain of 5000 pounds per square

inch of original section of the test piece until the stress is about 50,000 pounds per square inch of original section, when the additional loads should be in increments not exceeding 1000 pounds.

An observation to be made of the corresponding elongation measured upon the original length of eight inches.

The final elongation to be that obtained at rupture. The loads applied shall never be calculated from the indications of the pressure gauge if a hydraulic press be used.

CONDITIONS OF ACCEPTANCE.

In order to be accepted the average of the four test pieces must show an ultimate tensile strength of at least 60,000 pounds per square inch of original section, and a final elongation in eight inches of not less than 23 per cent.

Lots of material which show a strength greater than 60,000 pounds per square inch will be accepted, provided the ductility remains at least 23 per cent.

CASES OF FAILURE.

If the average of these four tests pieces, numbered 1, 2, 3, 4 (called Test I), fall below either of the required limits, the plates from which pieces 1, 2, 3, 4 were cut shall be rejected, and Test II made, consisting of pieces 5 and 6, cut from a third plate ; if the mean of the results of these two fall below either of the above limits the entire lot shall be rejected. If it be successful, Test III or the mean of pieces 7 and 8 cut from a fourth plate shall decide.

If in any of Tests I, II, III any single piece shows a tensile strength less than 58,000 pounds or a final elongation less than 21 per cent., the plate from which it was cut shall be rejected and that Test considered to have failed, regardless of its average.

QUENCHING TEST.

IV. A test piece shall be cut from *each* plate, angle or beam, and after heating to a cherry red, plunged in water at a temperature of 82° Fahrenheit. Thus prepared it must be possible to bend the pieces under a press or hammer so that they shall be doubled round a curve of which the diameter is not more than one and a half times the thickness of the plates tested without presenting any trace of cracking.

These test pieces must not have their sheared sides rounded off, the only treatment permitted being taking off the sharpness of the edges with a fine file.

ANGLES, BEAMS, BULB BARS, T BARS, &C.

V. In every lot of 20 angles or beams, &c., test pieces to be cut from the webs of two taken at random, one from each. These pieces to be fashioned in the same way, and to be subjected to the same tests, both tensile and quenching, and to fulfil the same requirements for acceptance as already prescribed for ship-plates.

Angle bars are to be subjected to the following additional tests : A piece cut from one bar in twenty to be opened out flat while cold under the hammer; a piece cut from another bar in the same lot shall be closed until the two sides

touch, while cold; a piece from a third bar of the lot to be bent cold into a ring so that one of the sides of the angle bar shall be kept flat and the other side forming a cylinder, of which the internal diameter shall be equal to 3½ times the breadth of the sides which remains flat. The angle bars submitted to these tests must show neither cracks, clifts nor flaws.

Single T bars to be submitted to the following tests: A piece to be cut from the end of a bar taken at random from each lot of 20, and to be bent cold into a half ring, so that the web remaining in its own plane, the cross flanges shall form a half cylinder, of which the internal diameter shall equal four times the height of the web of the T bar.

At the end of another bar of the same lot the web to be split down its middle for a length equal three times its total depth, and a hole drilled at the end of the slit to prevent it spreading; the piece thus split to be opened out in its own plane, so as to make an angle of 45° with the rest, care to be taken that the part opened shall be kept straight, except that it must be joined to the rest of the bar by a bend of small radius.

Bulb bars are to be subjected to the same tests as those prescribed for T bars, except that in bending one or more heats may be used.

All bars submitted to these tests must show neither cracks, clifts nor flaws.

RIVETS.

VI. One bar from every lot of 20 of the bars from which rivets are made shall be subject to the same tensile test as that required for the plate tests. All bars not fulfilling the requirements of tensile strength and elongation required for plates to be rejected.

From every lot of 500 pounds four rivets are to be taken at random and submitted to the following tests, one rivet to be used for each test: 1st. A rivet to be flattened out cold under the hammer to a thickness of one-half its diameter without showing cracks or flaws. 2d. A rivet to be flattened out hot under the hammer to a thickness one-third its diameter without showing cracks or flaws. 3d. A rivet to be bent cold into the form of a hook with parallel sides without showing cracks or flaws. 4th. A rivet to be tested by shearing by riveting it up to two pieces of steel which are to be submitted to a tensile strain, the rivet not to shear under a stress of less than 50,000 pounds per square inch.

BOILER PLATES.

VII. *Each* boiler plate must be subjected to the same tests and in the manner prescribed for ship plates. The ductility in eight inches must not be less than twenty-five per cent., and the ultimate tensile strength must not be less than 57,000 pounds and not more than 63,000 pounds, and the average at least 60,000 pounds.

The acceptance of material under these tests will not relieve the contractor from the necessity of making good any material which fails in working or may be rejected by the Inspector.

APPENDIX II.

England—Ships of War Building, 1883–84.

Name.	Class.	Type.	Displacement.	Horse power	Speed knots.	Armament.
ARMORED.						
Battle ships—						
Anson	1	Barbette Turrets	10,000	7500	16	IV 15-in. 63-ton B.L.R.; VI 6-in. B.L.R.; XIV machine guns.
Benbow	"	" "	"	"	16	II 17-in. 100-ton " X " " XIV " "
Camperdown ...	"	" "	"	"	16	IV 15-in. 63-ton " VI " " XIV " "
Collingwood	"	" "	9150	7000	16	IV 12-in. 43-ton " VI " " XIV " " 12 Whitehead torpedoes.
Colossus	"	Turrets	"	6000	14	IV " " " V " " XIV " " 12 " "
Edinburgh	"	"	"	"	14	IV " " " V " " XIV " " 12 " "
Howe	"	Barbette Turrets	9600	7500	15	IV 15-in. 63-ton " VI " " XIV " " 12 " "
Rodney	"	" "	"	"	15	IV " " " VI " " XIV " " 12 " "
Coast guard—						
Conqueror	3	Turrets.	6200	4500	13	II 12-in. 43-ton " IV " " IX " " 18 " "
Cruiser—						
Impérieuse	2	Barbette Turrets.	7390	8000	16	IV 9.2-in. 18-ton " VI " " XIV " " 12 " "
Warspite	2	" "	"	"	16	IV " " " VI " " XIV " " 12 " "
UNARMORED.						
Mersey	2	Protected Cruiser	3550	6000	..	XIV " " VIII " " 10 " "
Severn	"	" "	"	"	..	Unassigned; probably the same as that of Mersey. VIII " " 10 " "
Amphion	"	Steel Cruiser	3750	5000	..	X 6-in. B. L. R.; VIII machine guns; 10 " "
Arethusa	"	" "	"	"	..	X " " VIII " " 10 " "
Leander	"	" "	"	"	..	X " " VIII " " 10 " "
Phaeton	"	" "	"	"	..	X " " VIII " " 10 " "
Calypso	"	Steel Corvette	2770	3000	13.75	IV " " XII 5-in. B. L. R.; VI machine guns; 6 Whitehead torpedoes.
Calliope	"	" "	"	"	..	IV " " XII " " VI " " 6 " "
Cordelia	"	" "	2380	2420	13.25	X " " VI " " 6 " "
Caroline	Sloop	Composite	1420	1500	..	II " " X " " IV " "
Pylades	"	"	"	950	..	II " " X " " IV " "
Rapid	"	"	"	"	..	II " " X " " IV " "
Royalist	"	"	"	"	..	II " " X " " IV " "
Mariner	Gun vessel	"	950	850	..	II " " II " " II " "
Mariner (new)	"	"	"	"	..	II " " II " " II " "
Mariner (new) ...	"	"	"	"	..	II " " II " " II " "
Racer	"	"	"	"	..	II " " II " " II " "
Reindeer	"	"	"	"	..	II " " II " " II " "
Wanderer	"	"	925	750	..	II " " II " " II " "
Acorn	"	"	950	850	..	II " " II " " II " "
Dolphin	"	"	925	750	..	II " " II " " II " "
Albacore	Gunboat	"	560	600	..	II 5-inch " II 4-inch " II " "
Mistletoe	"	"	"	"	..	II " " II " " II " "
Watchful	"	"	"	"	..	II " " II " " II " "
Sphinx	Gun vessel	Composite (paddle wheel)	1130	1000	..	I 6-in. " VI " " II " "

Twenty-one (21) torpedo boats are building on the Thames. Six (6) wooden torpedo boats are building at Isle of Wight.

France—Ships of War Building, 1883–84.

Name.	Class.	Type.	Displacement	Horse-Power.	Speed knots.	Armament.
ARMORED. Cruising Ironclads						
Admiral Baudin	1	Barbette Turrets	11,441	1625 (nom.) 7397 (indic.)	16	III 100-ton B. L. R.; XII 5.5-in. B. L. R.; VIII machine guns.
Formidable....	"	" "	11,441	1500 (nom.)	16	III " " XII " " VIII " "
Foudroyant.....	"	" "	9639	1500 (nom.) 8000	14.2	IV 34 cm. (13.5-in.) R.; II 27 cm. (10⅝-in.) R.; VI 14 cm. (5.5-in.) R.; VIII machine [guns.
Brennus	"	Turrets	9780	3383	14	IV 34 cm. (13.5-in) R.; VI 27 cm. (10⅝-in.) R.; VIII 24 cm. B. L. R. ‡
Charles Martel..	"	"	9780	3383	14	IV 34 cm. B. L. R.; VI 27 cm. B. L. R.; VIII 24 cm. B. L. R. ‡
Indomptable....	"	"	7184	6000 (nom.)	14.5	II 16.5-in. 74-ton B. L. R.; IV 4-in. B. L. R.; IV machine guns.
Neptune........	"	"	9861	1625 (nom.)	15	[III 34 cm. (13.5-in.)R.; IV 27 cm. (10⅝-in.) R.;]* XVIII 14 cm. (5.5-in.) R.
Hoche..........	"	"	9864	1625 (nom.)	15	[III " B. L. R.; IV 27 cm. B. L. R.];* XVIII 14 cm. (5.5-in) R.; VIII machine guns.
Magenta........	"	"	9864	1625 (nom.)	45	Same as *Hoche*.*
Marceau........	"	"	"	1625	..	" " " *
Furieux	Monitor	"	5695	4150	14	II 13.5-in. 47-ton B. L. R.;† IV Hotchkiss revolving guns.
Terrible	"	"	7184	6000	14.5	II 16.5-in. 74-ton B. L. R.; IV 4-in. B. L. R.; IV machine guns.
Caïman	"	"	7239	6000	14.5	II " " " IV " " IV " "
Requin	"	"	7184	6000	14.5	II " " " IV " " IV " "
N	..	No data	..	..	..	
N	..	"	..	..	..	
Station Ironclads—						
Duguesclin......	2	Turrets	5869	4100	14	IV 24 cm.(9.5-in) B.L.R.; I 19 cm. (7.5-in.) B.L.R.; VI 14 cm. (5.5-in.) B.L.R.; VIII machine [guns.
Vauban........	"	"	"	"	"	IV " " " I " " " VI " " " VIII "
Ironclad Gunboats						
Acheron	1	"	1639	..	..	I 10¾-in. B. L. R.; II 4-in. B. L. R.
Cocyte.........	"	"	"	..	.	I " " II " "
Phlégéton	"	"	"	..	..	I " " II " "
Styx	"	"	"	..	..	I " " II " "
Flamme.........	2	Steel-armor Plated	1045	..	..	I 9.5-in. B. L. R.; I 3.5-in. B. L. R.; II machine guns.
Fusée......	"	" "	"	..	..	I " " I " " II " "
Grenade........	"	" "	"	..	..	I " " I " " II " "
Mitraille........	"	" "	"	..	..	I " " I " " II " "
Gundeck Cruisers—						
Dubomdieu	..	Wood	3355	..	..	IV 16 cm. guns; XXII 14 cm. (5.5-in.) guns. (Carnet.)
Sfax............	..	"	4488	5000	..	IV " " XXII " " " "
Skirmisher—						
Milan...........	..	No data	..	..	..	

* It is probable that three 100-ton guns will be substituted for these.
† It is probable that two (2) 42 cm. (16.5-in.) guns will be substituted for these.
‡ Carnet de l'officier de Marine, 1883.

France—Ships of War Building, 1883–84.—(CONTINUED.)

Name.	Class.	Type.	Displacement.	Horse-Power.	Speed knots.	Armament.
Torpedo Skirmishers—						
Condor	..	No data	..	..	..	
Epervier	..	"	..	..	..	
Faucon	..	"	..	..	..	
Vautour	..	"	..	..	..	
Station Despatch Vessels and Gunboats—						
Fulton	..	Wood	811	1000	12.5	IV 14 cm. (5.5-in.) B. L. R.
Inconstant	..	"	"	"	"	IV " " "
Papin	..	"	"	"	"	IV " " "
Comète	..	......	..	..	..	
Méteore	..	......	..	..	..	
Etoile	..	Composite	..	..	..	
Gabes	..	......	..	..	..	
Lion	1	Composite	473	..	..	
Scorpion	"	"	"	..	..	
Large Transports—						
Gironde	Troop Ship	Iron	5775	2500	13	IV 14 cm. (5.5-in.) B. L. R. (Carnet.)
Nive	"	"	"	"	"	IV " " " "
Mixed Transports						
Magellan	Transport	"	3991	657	11	VII " " " "
Calédonien	"	"	"	"	"	VII " " " "
Despatch Transports—						
Meuthe	"	Wood	1597	"	"	VII " " " "
Durance	"	"	"	"	"	VII " " " "
Flotilla Despatch Vessels—						
Ardent	..	Iron	486	440	..	III Hotchkiss guns.
Brandon	..	"	"	"	..	III " "
N	..	......	..	.	..	
N	..	......	..	..	..	
Ibis	..	Iron	254	..	..	II 2.5-in. B. L. R.; II machine guns.
Alcyon	..	......	..	40 (nom.)	..	IV Hotchkiss guns.
Jouffroy	..	......	..	"	..	IV " "
Sailing Frigates—						
Andromède	..	No data	..	..	..	
Melpomène	..	"	..	..	..	
Sailing Brigs—						
Bayonaise	.	"	..	..	..	
Sylphe	..	"	..	..	..	

Italy, Spain, Brazil and Chili—Ships of War Building, 1883–84.

Name.	Class.	Type.	Displacement.	Horse-Power.	Speed knots.	Armament.
ITALY.						
Italia						
Lepanto	1	Barbette Turrets	13,898	18,000	16	IV 17-in. 100-ton B. L. R.; XI 6-in. B. L. R.
Ruggiero Lauria	"	" "	13,550	"	"	Same as *Italia's*.
Francesco Morosini	"	" "	10,045	10,000	..	IV 17-in. 100-ton B. L. R.
Andre Dorea	"	" "	"	"	..	IV " " "
UNARMORED.	"	" "	"	"	..	IV " " "
Amerigo Vespucci	..	Steel Corvette	2533	2500	15	VIII 6-in. B. L. R.
Savoia	..	Steel Yacht	2850	5000	..	IV " " II machine guns.
Giovanni Bausan	..	Torpedo Ram	3068	5500	17	II 10-in. 25-ton B. L. R.; VI 6-in. B. L. R.; IV machine guns.
N	..	" "	3530	6000	.	II 35-ton B. L. R.; VIII 12-ton B. L. R.
N	..	" "	"	"	..	II " " VIII " "
Sebastiano Veniero	..	(Steel) Gunboat	649	1000	18	VI 4.7-in. B. L. R.; II machine guns; X Whitehead torpedoes.
Andreo Provano	..	" "	"	"	"	VI " " II " " X " "
	Six (6) Iron Paddle-wheel Gunboats.		Four (4) 1st class Steel Torpedo-boats.			Eighteen (18) 2d class Steel Torpedo-boats.
SPAIN.						
Alfonso XII	1	Corvette	3090	4400	15.5	VIII 6-in. B. L. R; 4 Howitzers (Spanish).
Aristina	"	"	"	"	"	VIII " " 4 " "
Mercedes	"	"	"	"	"	VIII " " 4 " "
Clsido	..	Gunboat	217	240	8	I 4.7-in. B. L. R.; I 3.15-in. B. L. R.
Eulalia	..	"	"	"	"	I " " I " "
BRAZIL. ARMORED.						
Riachuela	1	Turrets	5700	6000	15	IV 9-in. 20-ton B. L. R.; VI 70-pdr. guns; XV Nordenfeldt machine guns.
ORDERED FOR 1884. 2 Ironclads. 2 Unarmored Cruisers. 2 Monitors. 12 Gunboats. 24 Torpedo-boats.	No data.					
CHILI. ARMORED.						
Esmeralda	Corvette	Turrets	3900	5500	17	II 27-ton guns: VI 6-in. B. L. R.
N	Building	Unarmored Cruiser	2500 (approx.)	..	..	II 10-in. 25-ton guns (?); II 6-in. B. L. R.: IV machine guns.
N	at Kiel.	" "	"	..	..	II " " " II " " IV " "

Germany, Holland, Russia, Turkey and Greece—Ships of War Building, 1883–84.

Name.	Class.	Type.	Displacement.	Horse-Power.	Speed knots.	Armament.
GERMANY.						
N	..	Barbette Turrets	5200	3900	..	
N	..	Ironclad Gunboat	1500	2700	16	I 4.7-in. B. L. R.; IV 3.4-in. B. L. R.
N	..	" "	"	"	"	I " " IV " "
N	..	Corvette	3360	..	..	
N	..	"	2370	2400	.	XII 6-in. B. L. R.; II 3.4-in B. L. R.
N	..	"	"	"	..	XII " " II " "
N	..	Gunboat	884	1500	15	I 12-in. B. L. R.; VI machine guns
N	..	Torpedo-ship	140	550	..	
HOLLAND.						
Doggersbank	1	Corvette	3160	3000	14.5	VI 6.7 B. L. R.; VI 4.7-in. B. L. R.
Kortenaer	"	"	"	"	"	VI " " VI " "
RUSSIA.						
Vladimir Monomach	..	(Armored)	5783	7000	16	IV 8-in. B. L. R.; XII 6-in. B. L. R.; VI machine guns.
Dimitri Donskoi	..	"	"	"	"	IV " " XII " " VI " "
Moskwa	..	"	"	"	"	Probably the same as that of Vladimir Monomach.
N	1	" Barbette Turrets	9990	9000	"	VI 30 cm. (11.8-in.) and VI 15 cm. (5.5-in.) B. L. R.
TURKEY.						
Mehemet Selim	..	Corvette	No data	..	..	
GREECE.						
Epiros	..	Corvette	2500	No data	..	
Thessalis	..	"	"	No data	..	

NAVAL INSTITUTE PRIZE ESSAY, 1884.

A Prize of one hundred dollars and a gold medal is offered by the Naval Institute for the best Essay presented, subject to the following rules :

1. Competition for the Prize is open to all members, Regular, Life, Honorary and Associate, and to all persons entitled to become members, provided such membership be completed before the submission of the Essay. Members whose dues are two years in arrears are not eligible to compete for the Prize until their dues are paid.

2. Each competitor to send his Essay in a sealed envelope to the Secretary on or before January 1, 1884. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the Essay a separate sealed envelope will be sent to the Secretary, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges to be three gentlemen of eminent professional attainments (to be selected by the Executive Committee), who will be requested to designate the Essay, if any, worthy of the Prize, and, also, those deserving honorable mention, in the order of their merit.

4. The successful Essay to be published in the Proceedings of the Institute, and the Essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Executive Committee.

5. Any Essay not having received honorable mention, to be published only with the consent of the author.

6. The subject for the Prize Essay is, "*The Best Method for the Reconstruction and Increase of the Navy.*"

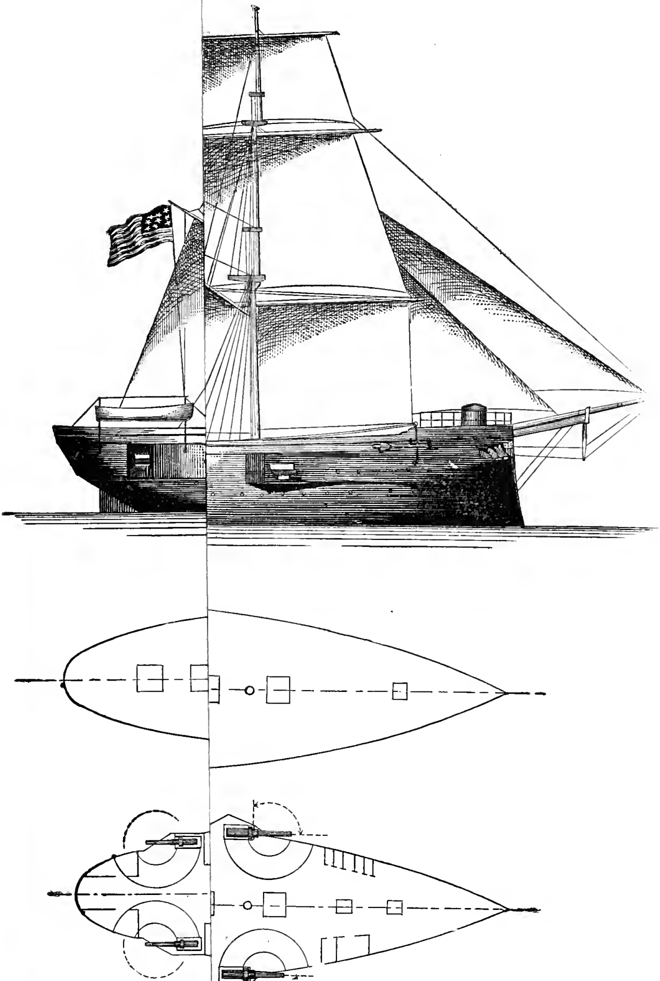
7. The Essay is limited to forty-eight printed pages of the "Proceedings of the Institute."

8. The successful competitor will be made a Life Member of the Institute.

9. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

CHAS. M. THOMAS,
Secretary.

ANNAPOLIS, MD., *May* 3, 1883.

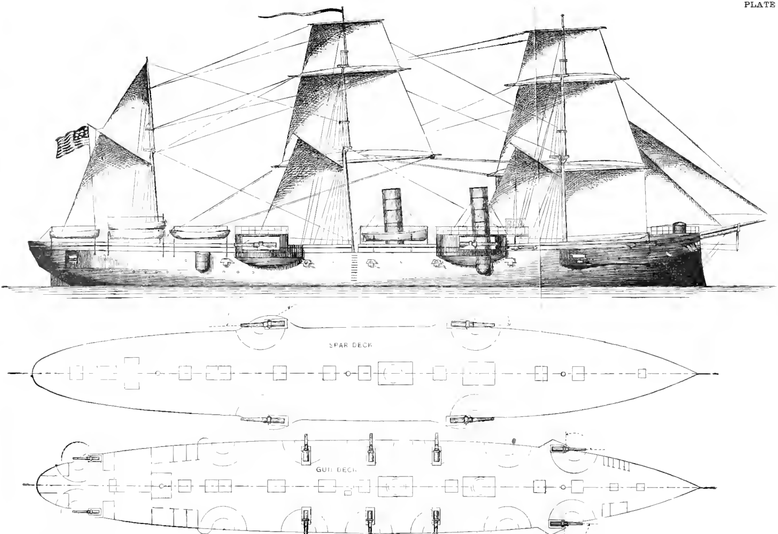


BATTERY.

Four 8-in B. L. R.
Eight 6-in B. L. R.
Two 5-in B. L. R.
Six Revolving Cannon

DIMENSIONS.

Length on water line, 325 Feet.
Beam, - - - - - - 48 Feet 2 Inches.
Draught, - - - - - 19 Feet.
Displacement, - 4,500 Tons.



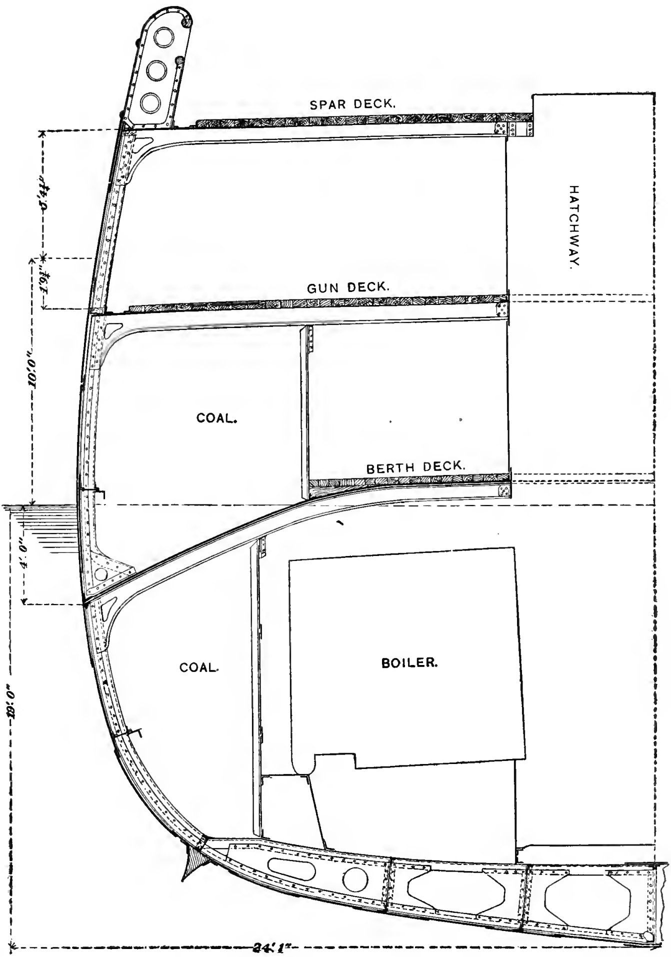
BATTERY
Four 8-in B. L. R.
Eight 6-in B. L. R.
Two 5-in B. L. R.
Six Revolving Cannon.

UNITED STATES TWIN SCREW STEAM CRUISER CHICAGO.

DIMENSIONS.
Length on water line, 325 Feet.
Beam, - - - - - 48 Feet 2 Inches.
Draught, - - - - 19 Feet.
Displacement, - 4,500 Tons.

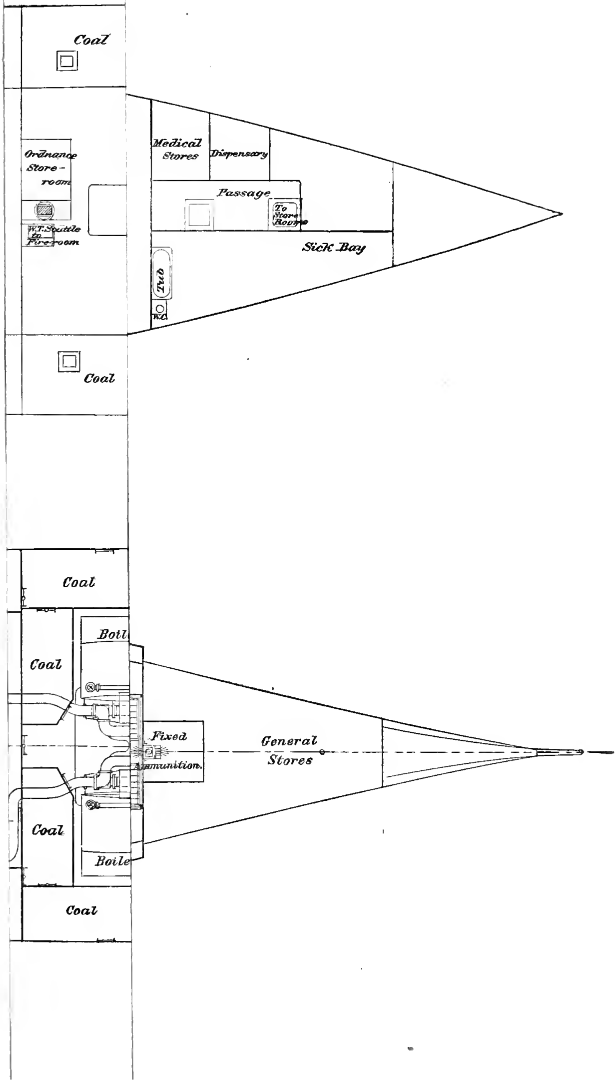
U. S. TWIN SCREW CRUISER CHICAGO. **PLATE II.**

Midship Section.



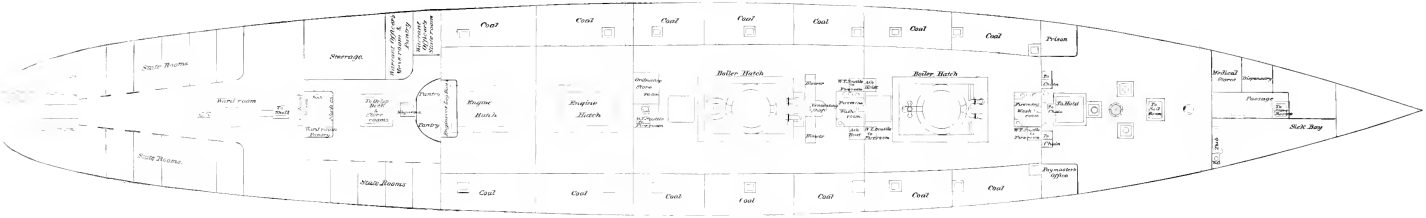
U. S.

PLATE III.

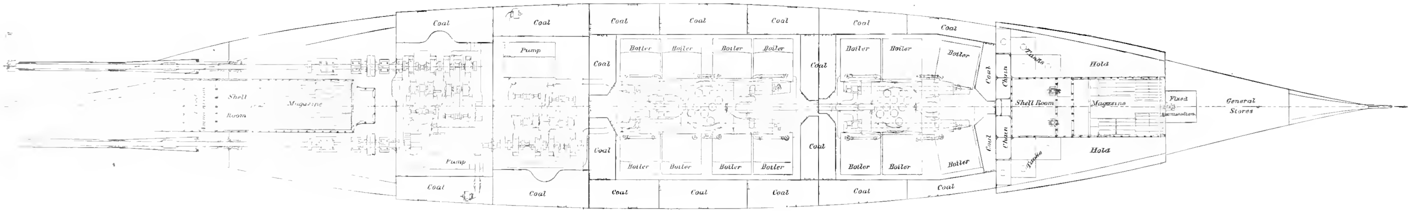

Coal
Ordnance Store-room
W.T. Scuttle to Fire-room
Medical Stores
Dispensary
Passage
To Store Room
Sick Bay
Tub
W.C.
Coal
Coal
Boil
Coal
Fixed Ammunition.
General Stores
Coal
Boile
Coal

U. S. STEAM CRUISER CHICAGO.

Plan of Berth Deck.



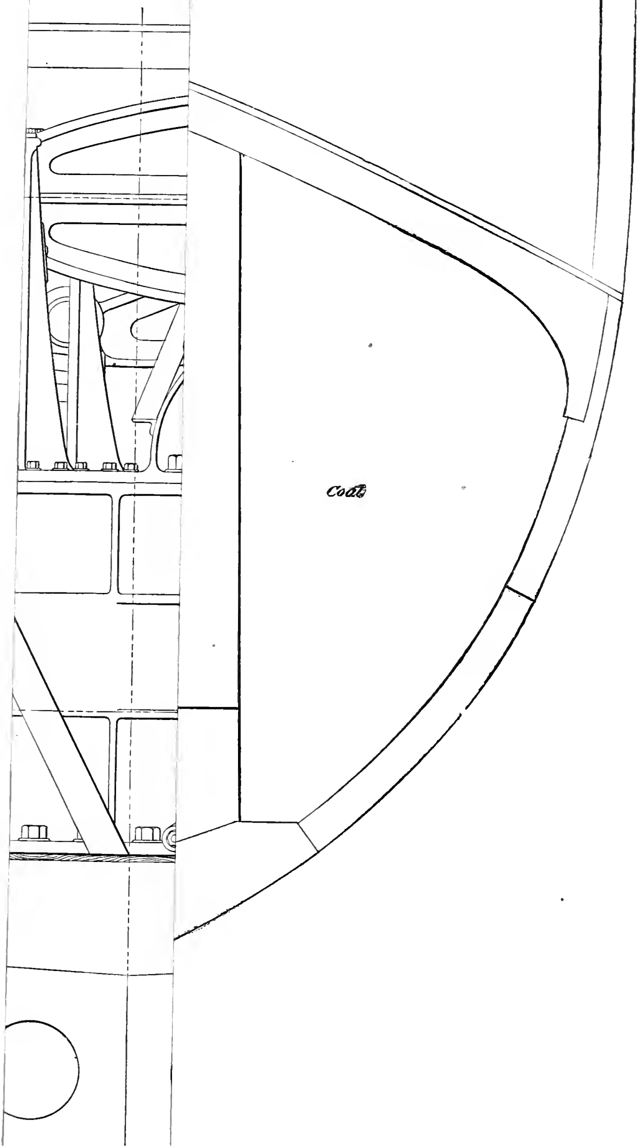
Plan of Hold.



TEAM CRUISER

ction and Eleva

PLATE IV.



U. S STEAM CRUISER CHICAGO

Traneverse Section and Elevation of Machinery.

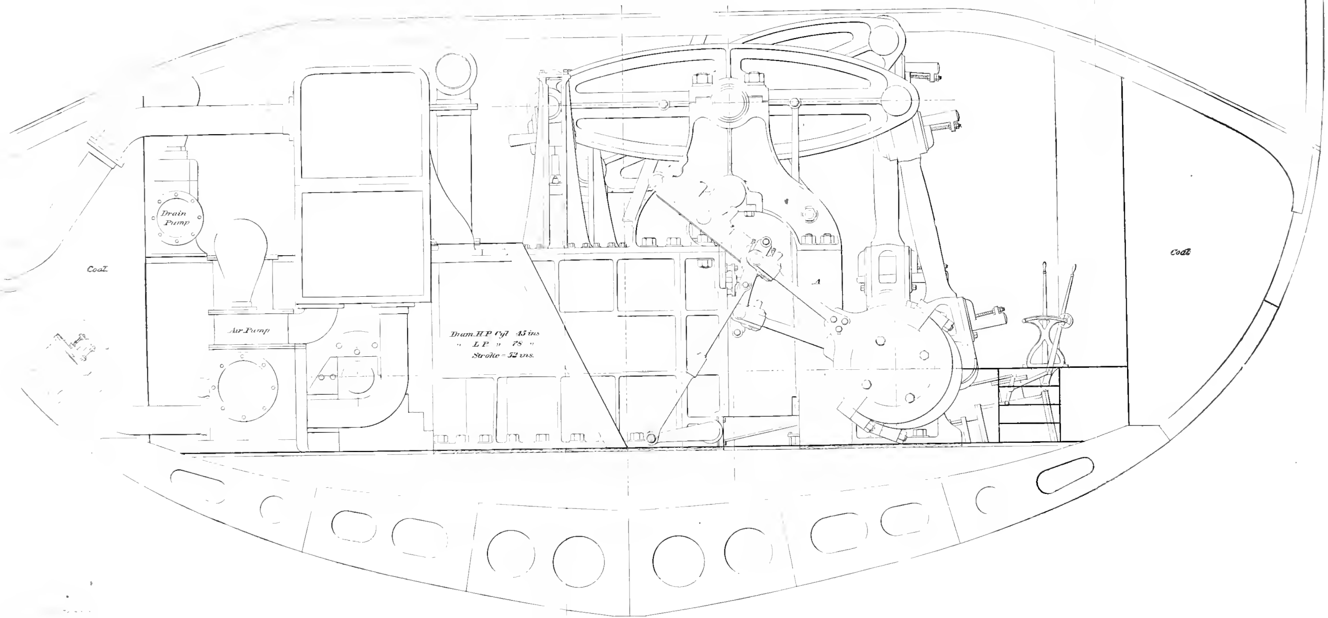
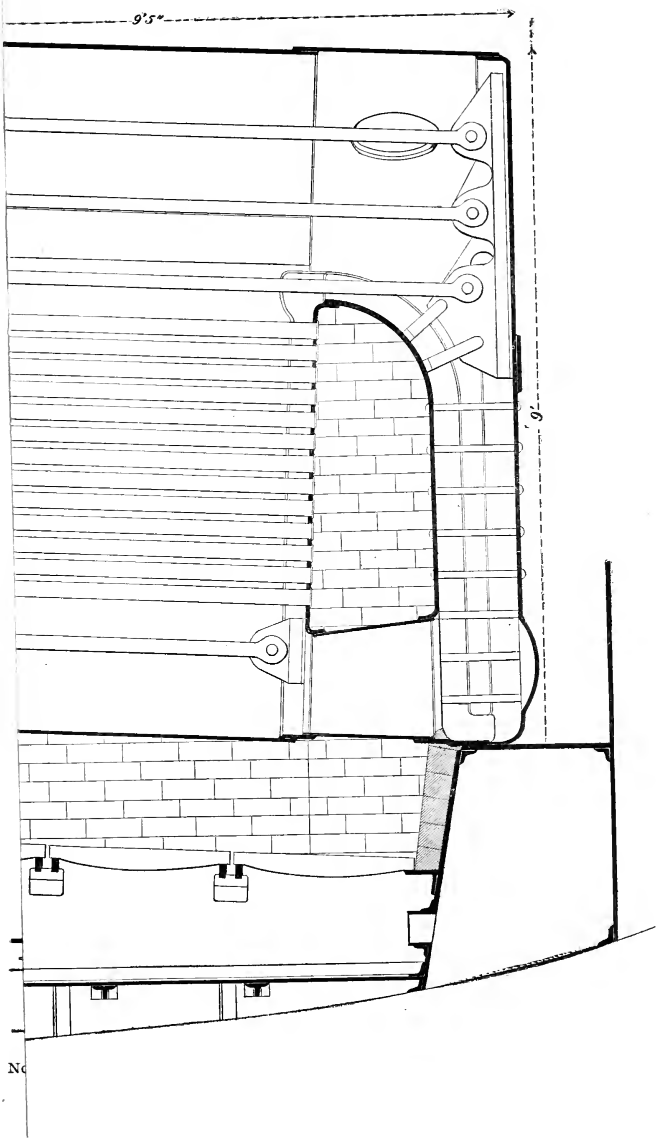


PLATE V.



UNITED STATES STEAM CRUISER CHICAGO.

Sections and Elevation of Boilere.

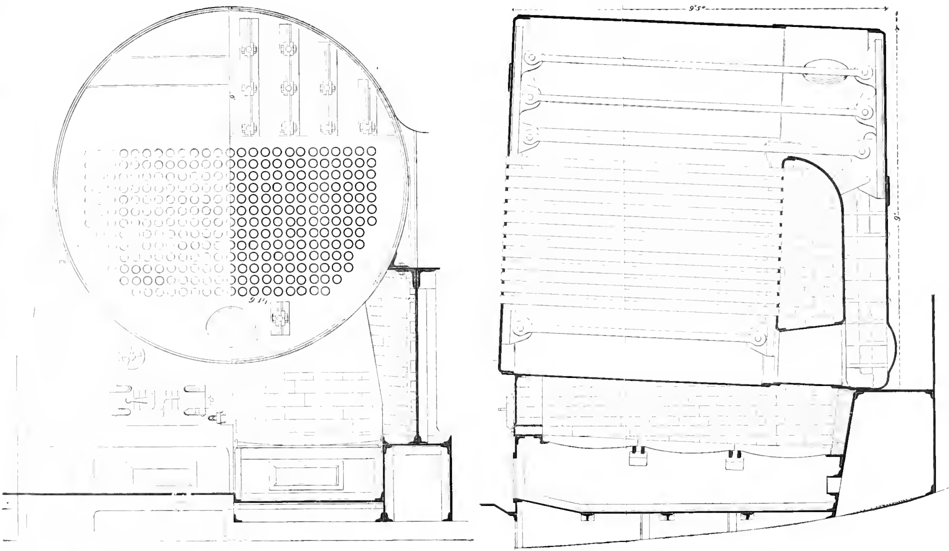
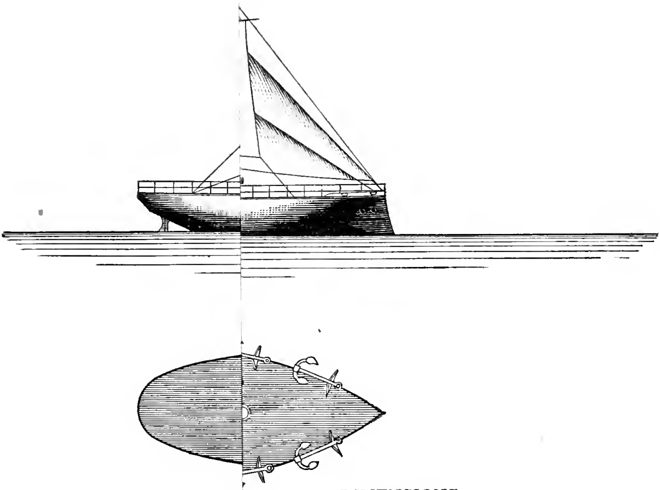


PLATE VI.



BATTERY

Two 8-in. B. L. R

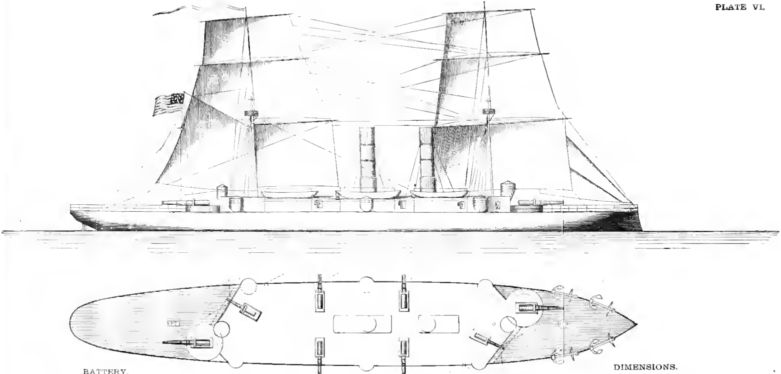
Six 6-in. B. L. R.

Eight Revolving

DIMENSIONS.

Length - - - - -	270 Feet.
Beam - - - - - - -	42 Feet.
Draught - - - -	17 Feet.
Displacement	- 3,000 Tons.

PLATE VI.



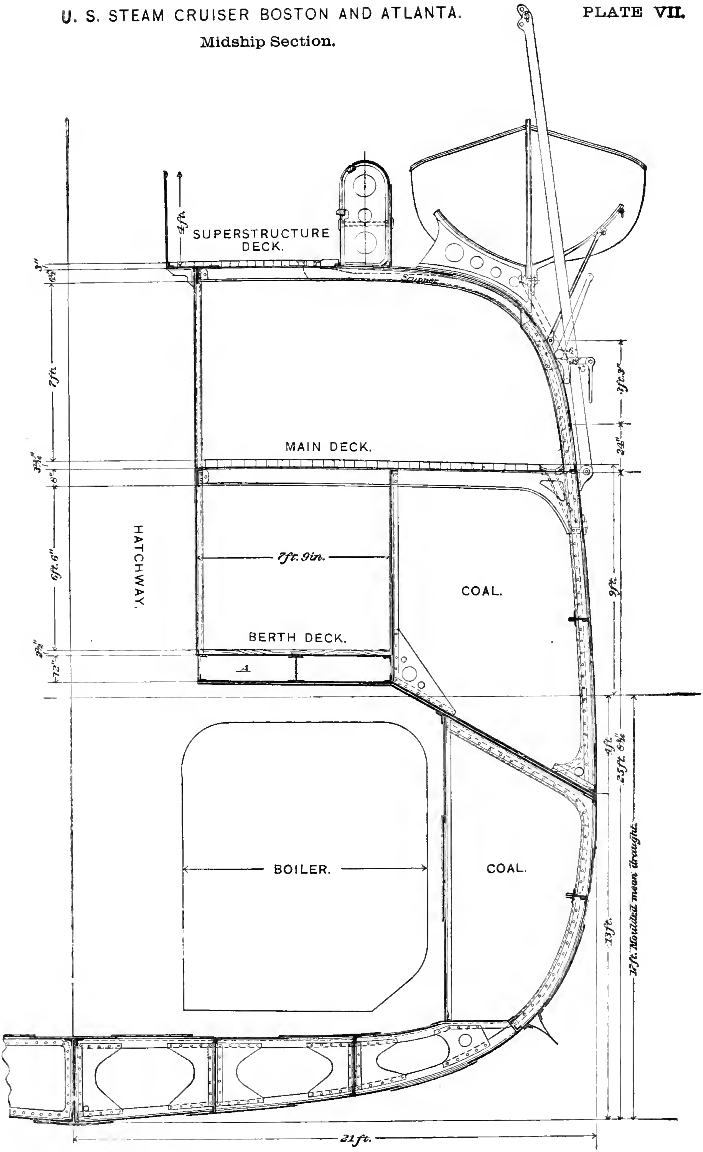
BATTERY.
Two 8-in B L R
Six 6-in B L R
Eight Revolving Cannon.

UNITED STATES STEAM CRUISER BOSTON OR ATLANTA.

DIMENSIONS.
Length - - - - - 270 Feet.
Beam - - - - - - 42 Feet.
Draught - - - - 17 Feet.
Displacement - 3,000 Tons.

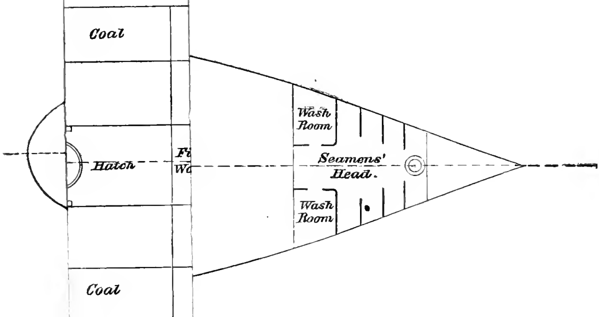
U. S. STEAM CRUISER BOSTON AND ATLANTA. PLATE VII.

Midship Section.

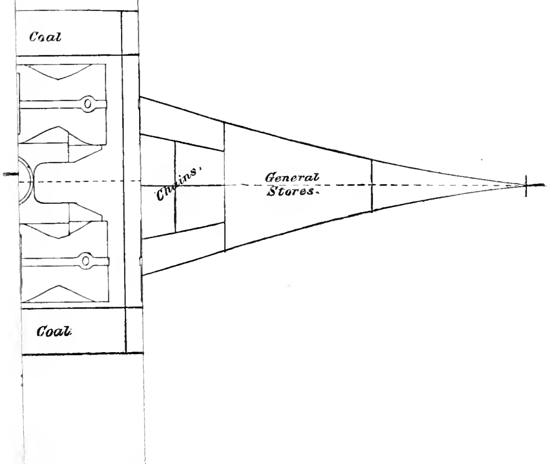


BOSTON AND

rth Deck.



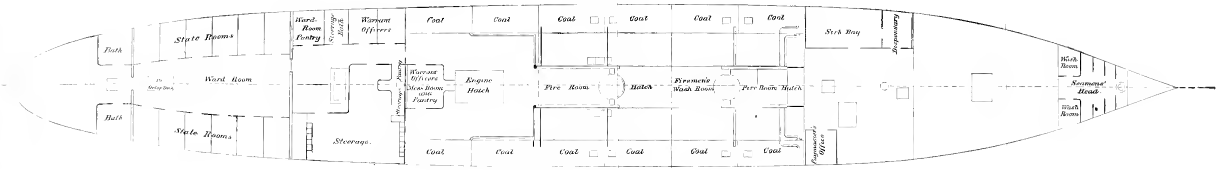
Hold.



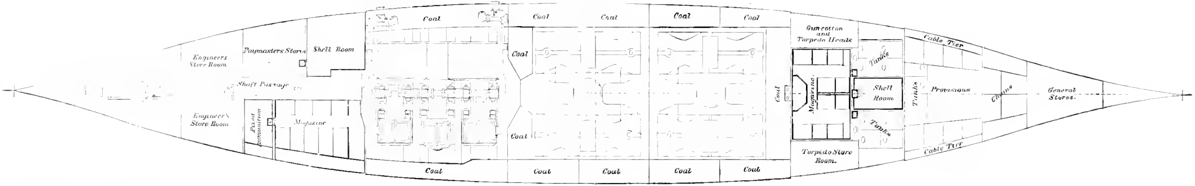
U. S. STEAM CRUISERS BOSTON AND ATLANTA.

PLATE VIII.

Plan of Berth Deck.

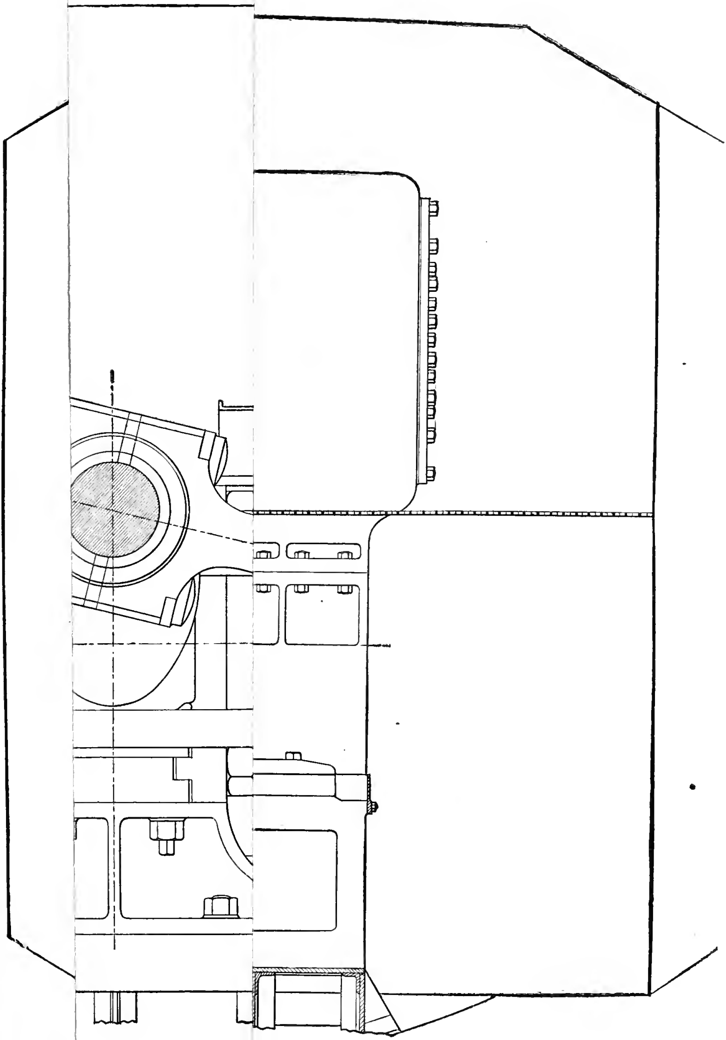


Plan of Hold.



RUISERS BOSTON

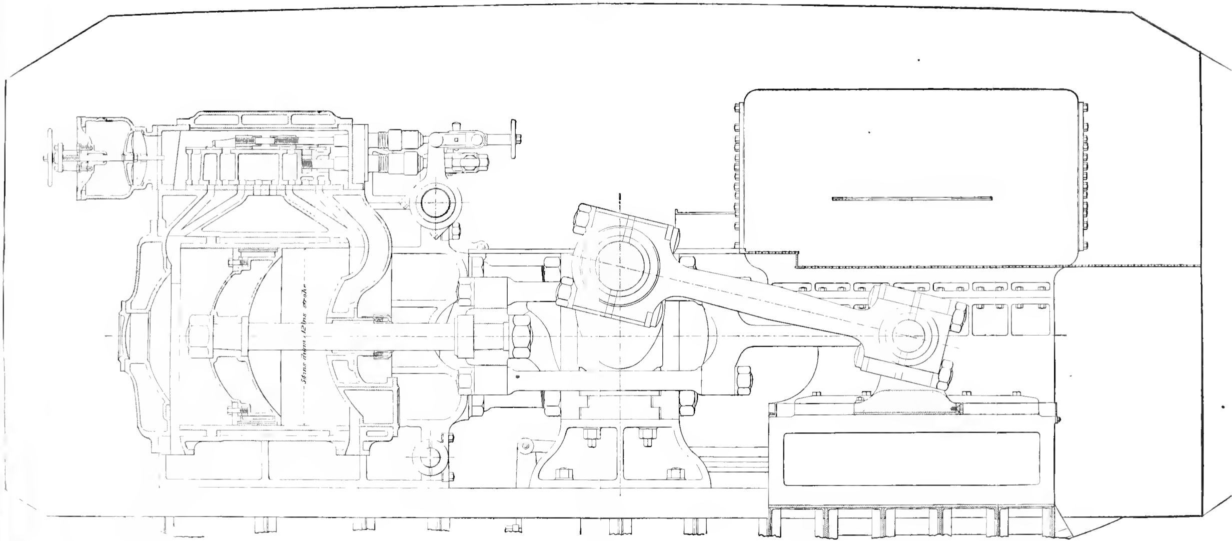
on of Machinery th



No. 26.

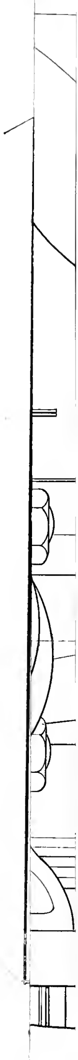
UNITED STATES STEAM CRUISERS BOSTON AND ATLANTA

Transverse Sections and Elevation of Machinery through H. P. Cylinder.



ON A

thro



No.

UNITED STATES STEAM CRUISERS BOSTON AND ATLANTA.

Transverse Sections and Elevation of Machinery through L. P. Cylinder.

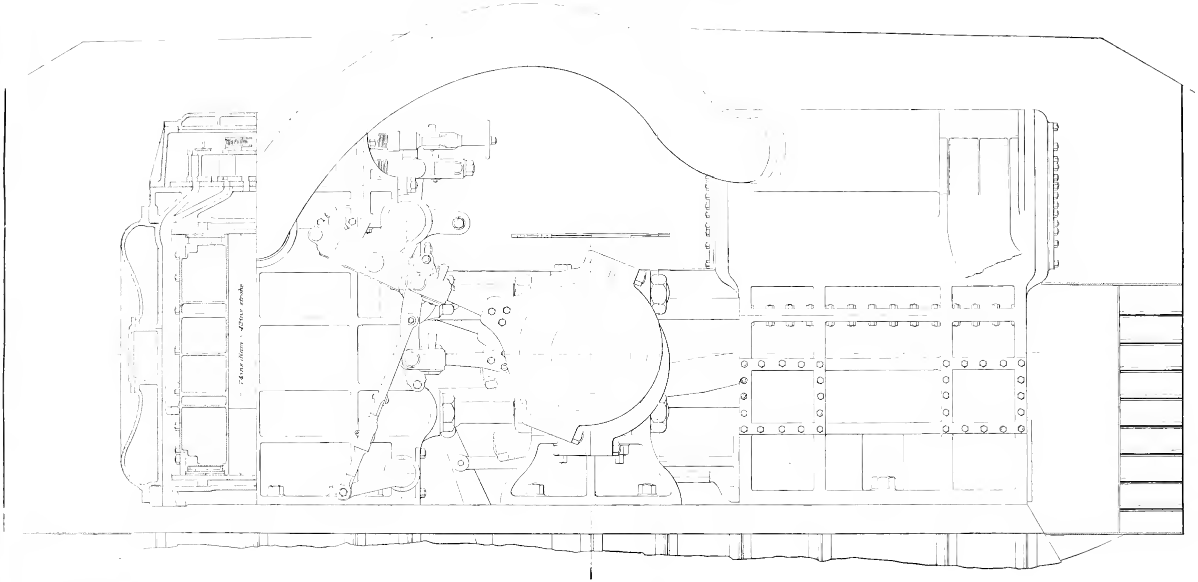
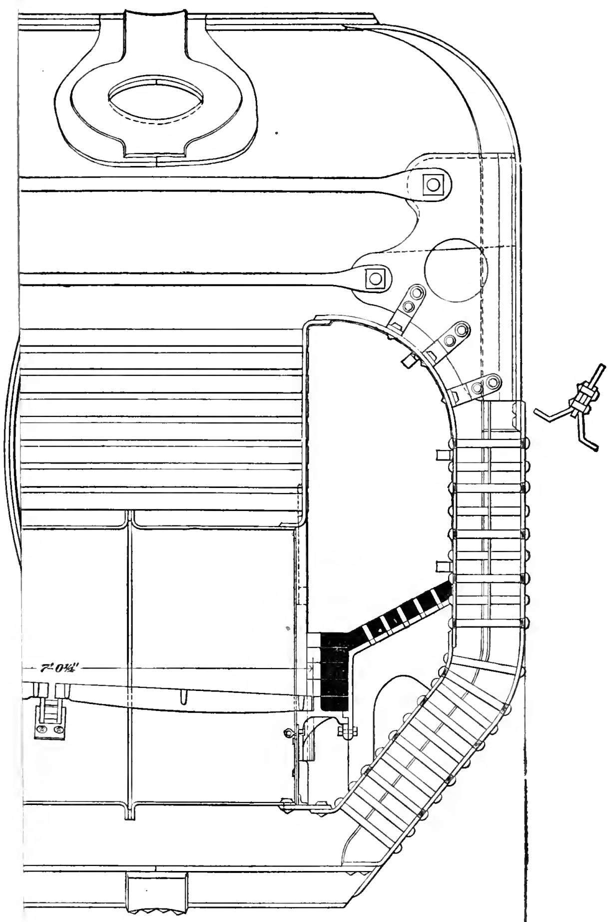


PLATE XI.



U. S. STEAM CRUISERS BOSTON AND ATLANTA.

Sections and Elevation of Boilers.

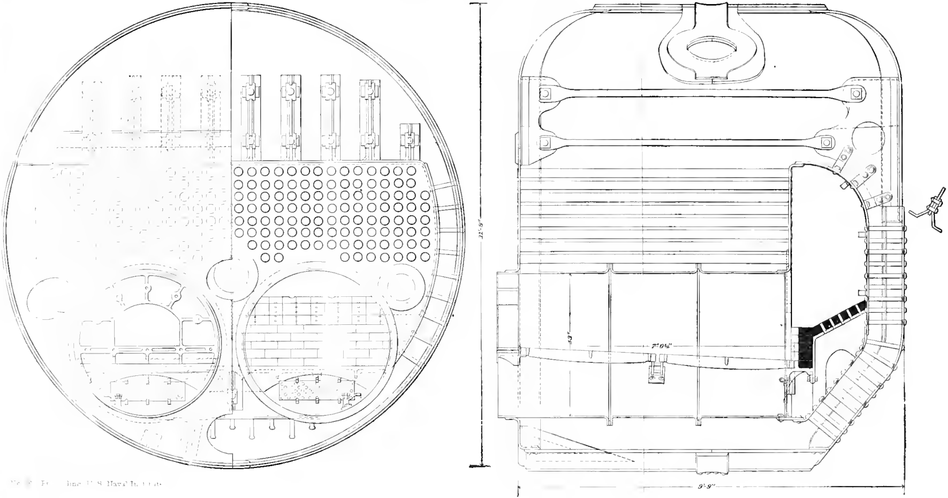
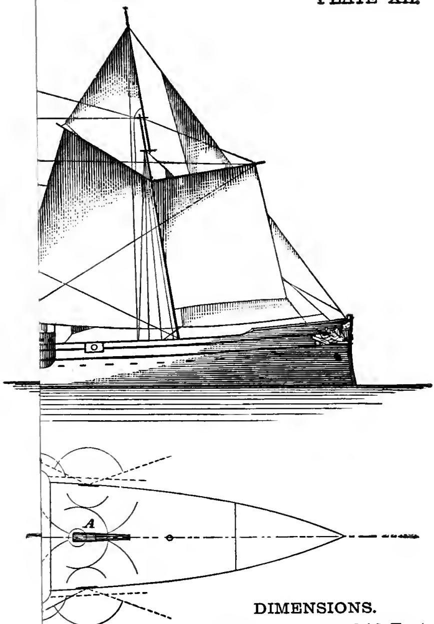


PLATE XII.



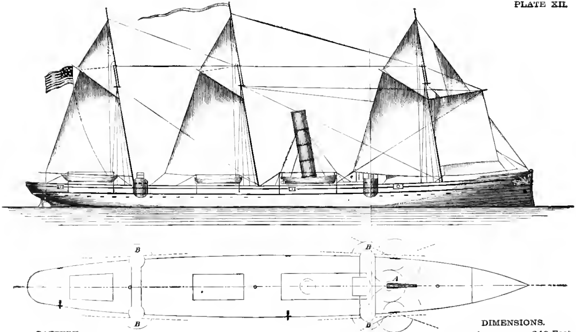
DIMENSIONS.

Length - - - - 240 Feet.
Breadth - - - - 32 Feet.
Displacement - 1500 Tons.

A
B PHIN.

No.

PLATE XII.

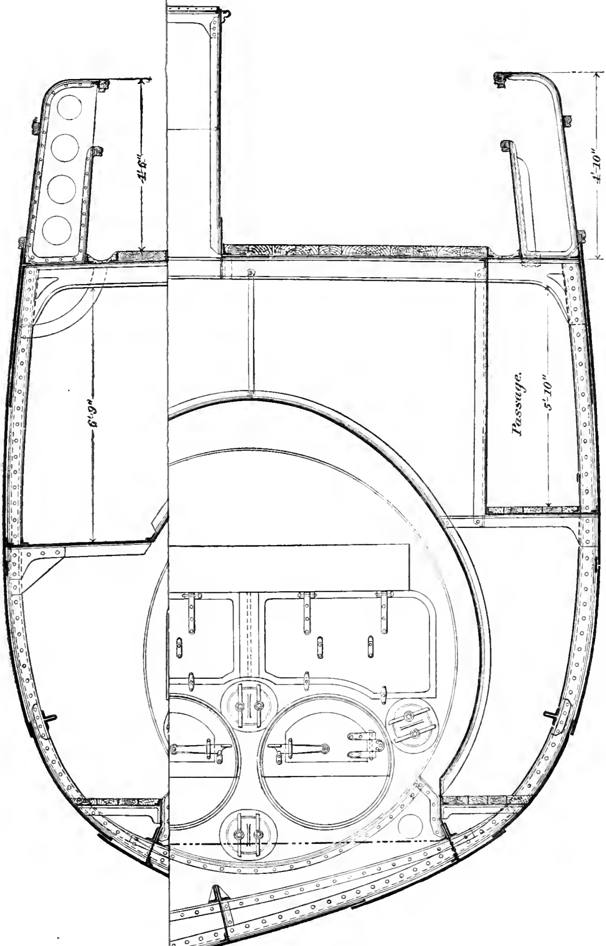


BATTERY.
A—6-inch B. L. R.
B—Revolving Cannon.

UNITED STATES DISPATCH BOAT DOLPHIN.

DIMENSIONS.
Length - - - - 240 Feet.
Breadth - - - - 32 Feet.
Displacement - 1500 Tons.

PLATE XIII.



U. S. DISPATCH BOAT DOLPHIN.

PLATE XIII.

Midship Section.

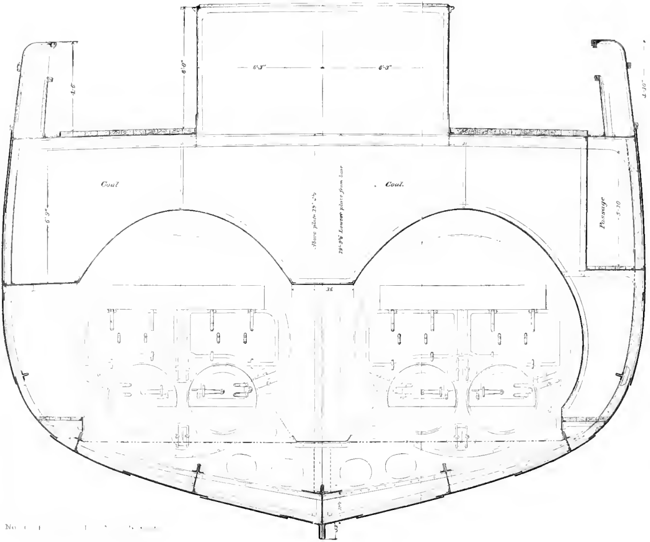
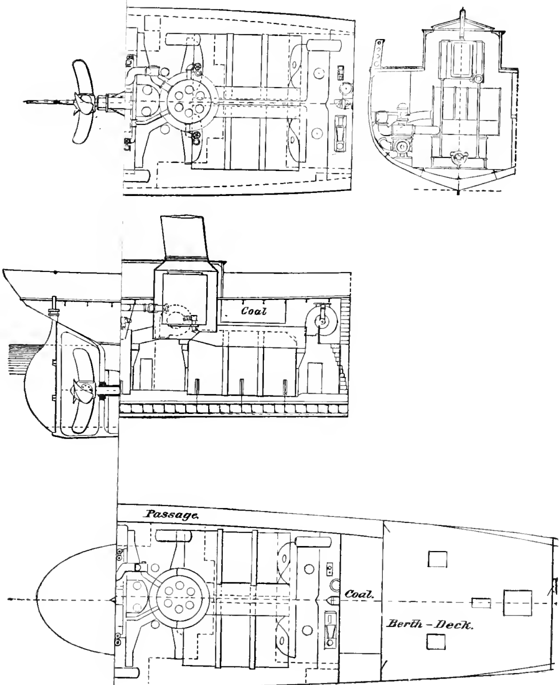


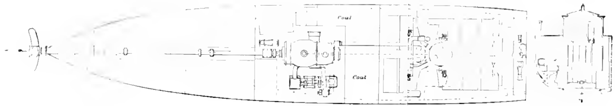
PLATE XIV.

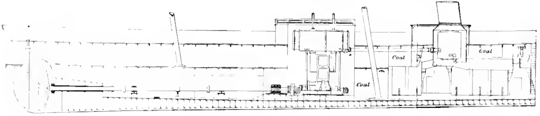
Elevation.



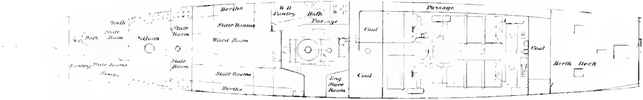
U. S. DISPATCH BOAT DOLPHIN

General Arrangement of Machinery. Plan and Elevation.





Plan of Berth Deck



Vol. IX., No. 5. 1883. Whole No. 27.

PROCEEDINGS

OF THE

UNITED STATES

NAVAL INSTITUTE.

VOLUME IX.

PUBLISHED QUARTERLY BY THE INSTITUTE.

ANNAPOLIS, MD.

PRESS OF ISAAC FRIEDENWALD,
BALTIMORE, MD.

// THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. IX. No. 5. 1883. Whole No. 27.

NAVAL INSTITUTE, NEWPORT BRANCH.

APRIL 4, 1883.

CAPTAIN THOMAS O. SELFRIDGE, U. S. N., in the Chair.

WAR SCHOOLS.

BY COMMODORE STEPHEN B. LUCE, U. S. N.

In establishing a branch of the Naval Institute at Coasters Harbor Island (Newport), I beg leave to avail myself of so fitting an occasion to offer a few remarks on the subject of the higher education of naval officers. Before doing so, however, it is only proper that we should refer, in passing, to the work already accomplished by the Institute, and offer our congratulations to the editors and managers on their undoubted success.

The Institute has flourished now for ten years, and in that time has been the medium of dissemination throughout the service of much that is of permanent value. The last issue, Vol. VIII, No. 4, is an exceedingly interesting and valuable contribution to our professional literature, and gives evidence of an extent of reading, of study, and of observation, which is a gratifying indication of the tendency of thought in the Navy—an indication of a tendency towards higher and broader fields of investigation. This is a healthy and hopeful sign of the future, and must lead up to some systematized effort to establish a means by which this evident desire for professional improvement may be gratified and encouraged.

The volume just quoted furnishes some excellent articles on the recent Egyptian campaign (1882), and one of them gives us a good hint of the useful work now being accomplished by the lately organized Office of Naval Intelligence. Ensign C. C. Rogers, for example, has given us a very interesting account of the bombardment of Alexandria (accompanied by a map of the scene of operations), the materials for the article having been drawn from the files of the Office of Intelligence. There are articles upon the same subject by Ensigns Griffin, Gleaves, McCarteney; an article on the "English Naval Brigade and Batteries in Egypt," by Lieutenant Charles F. Norton; one on "The Armored Train used by the English Forces at Alexandria," by Lieutenant N. H. Barnes; one on "Transports," by Lieutenant A. V. Wadhams; "Hospital Service of Army in Egypt," by Surgeon J. W. Coles; and "Subsistence of Soldiers, Sailors and Marines in Egypt," by Paymaster J. Q. Barton. These articles, treating of operations in the very highest branch of our profession—war—give to this number of the Journal a value it would not otherwise possess.

If we look in other directions the indications are equally encouraging. Naval Cadets Dixon and Schock, now studying Naval Architecture at the Royal Naval College, Greenwich, England, are manfully and, as we are happy to learn, successfully following the example set them by Assistant Naval Constructors Gatewood and Bowles. There are now, or have been, at least a dozen young officers studying at the Smithsonian Institute, Washington. Of the class of 1879, six were ordered there early in January, 1882.

Ensign R. H. Miner took up Ichthyology, made a summer cruise in the Fish Hawk, resumed his studies in the fall, and was detached in December, and ordered to the Fish Commission Steamer Albatross.

Ensign E. E. Hayden took up Mineralogy last summer, went on the Army Geological Survey to Nevada, and this winter took up the study of Fossil Botany.

Ensign H. S. Chase took up Mineralogy, went on a geological expedition to Montana last summer, and is now studying the same branch.

Ensign L. M. Garrett took up Geology, was in Montana last summer, and has resumed the same branch.

Ensign C. C. Marsh took up Ethnology, went on an ethnological expedition to Moquis, Arizona, last summer, and has taken up Fossil Botany this year.

Ensign J. B. Blish took up Marine Invertebrates, went in the Fish

Hawk last summer, resumed the same branch in the fall, and was last January detached at his own request and ordered to the Jamestown.

Of the class of '80, six were detailed last fall:

Ensign H. G. Dresel is studying Ichthyology.

Ensign J. B. Bernadou is engaged in the Chemical Laboratory in Quantitative and Qualitative Analysis and Assaying.

Ensign A. A. Ackerman is studying Mineralogy.

Ensign A. P. Niblack is studying Ethnology.

Ensign E. Wilkinson has taken up Mineralogy.

Ensign W. E. Safford has taken up Marine Invertebrates. Total, 12.

Each one is engaged in the practical work of the several departments in installing, identifying, and classifying, as far as able, the collections received from various sources.

Professor Baird, who kindly furnished this information, in speaking of one of the young naval officers studying under him, says: "He has already rendered very great service to the Institution in connection with ethnological research, and will be thoroughly well qualified to take advantage of any opportunity he may have of studying the manners and conditions of the savage or semi-civilized tribes that he may encounter in the course of his naval duty." These remarks of the Professor show the object and scope of the studies pursued by our young officers at the Museum. It is the beginning of a corps of naval scientists who will, by their researches and contributions to scientific literature, add greatly to the usefulness and reputation of our profession.

The excellent schools of practice furnished by the Naval Observatory, Naval Academy, Experimental Battery, and Torpedo Station, are all too well known, and their value—in a professional point of view—too well established to need more than passing mention.

UNITED STATES ARTILLERY SCHOOL.

If we turn to the army, we find that the need for a more extended course of study than is practicable at the Military Academy, or in the ordinary routine of active service, has long been recognized and in a great measure supplied. The United States Artillery School at Fort Monroe was established as far back as 1823. Its present organization, however, dates from 1867.

Some idea of the Artillery School may be obtained from the fol-

lowing extracts from the recent report of General John C. Tidball, U. S. A., of an inspection of the School in May last:

"The organization adopted in 1867 contemplated more than mere drill exercises. It is a course of studies and practical training not limited to what is necessary for merely expert artillerists, but one which aims to qualify officers for any duty they may be called upon to perform, or for any position, however high in rank or command, they may aspire to in service. Such an advance is demanded by the progress made in the methods of warfare during the last twenty years, particularly as regards artillery, wherein improvement has been from almost primitive rudeness to the requirements of an exact science, combining with it many cognate branches heretofore considered of little or no importance to a military man.

"Fort Monroe was selected as the place for the school because, from its size and position, it affords superior facilities in way of ample accommodations for officers and men, plenty of space for every kind of drill exercise and artillery firing, and emplacements for every variety of ordnance.

"The class just graduated consisted originally of 18 lieutenants of artillery, 2 of cavalry, and 1 of infantry, all of whom graduated excepting one resigned from the service, one transferred to the Ordnance Department, one assigned to duty in the Signal Corps, and two as professors at colleges.

"To arrive at what to-day is considered a respectable degree of professional intelligence in artillery, certain preliminary qualifications are necessary, among which may be mentioned a high order of proficiency in mathematics.

"To insure this, the prescribed course of instruction provides that those not possessing the requisite knowledge in this branch shall receive instruction therein. During the first years of the school many required it, and mathematics constituted a prominent and dreaded feature of the course. Of late years it has been found necessary to give such instruction to only a few of the officers sent there.

"For the purposes of administration, the course of studies and practical exercises are arranged into departments, as follows:

1. Department of artillery.
2. Department of engineering.
3. Department of military art and science.
4. Department of law.
5. Department of practical military instruction.

" The first and fifth of these are placed under the supervision of one of the field officers, and the remaining three under the other. Captains of the instruction batteries are the instructors, and are assigned to the several branches by the commandant of the school.

" The course is both practical and theoretical, preference being given to the former wherever it is possible to do so. The extent to which this has been done will appear when mentioning the several subjects in detail.

" The members of each new class report for duty on May 1. Ten days are allowed them to settle and arrange their affairs. Instruction then commences with a preparation for the artillery firing practice to take place in the succeeding months of July and August. Practical telegraphy is the first thing taught, and each lieutenant is made capable of sending and receiving messages, so as to enable him to conduct with facility and accuracy the necessary observations during the firing. Signaling is also taught for the same purpose. These and some other similar exercises continue until the 10th of June, when the class is turned over to the instructor in engineering for the purpose of acquiring knowledge of the method of using plane-tables and other instruments employed in making firing observations, and of plotting the same. This continues until July 1, when, as before stated, firing practice begins.

" The months of July and August of each year are set apart for this practice, and during these months the course of studies is suspended, except so far as connected with the firing, to which every attention is given.

" In the meanwhile daily drills have taken place to familiarize the students with the service of the various pieces with which they are to fire. A regular roster is kept of the officers, apportioning them to the several duties connected with the firing, thus insuring to all an equal share of these important duties. While some are at the pieces conducting the firing, others are at the stations observing and recording the shots, or preparing ammunition, etc. Each lieutenant is allowed a certain number of shots from each piece. This allowance is quite liberal, so much so, that the two months allotted gives barely time enough for the firing.

" The utmost care is observed in this exercise. Every circumstance and condition connected with each shot is observed and recorded, and a full study made of the whole, thus securing the greatest amount of instruction possible from the practice. To aid in making the obser-

vations and recording the results, telegraphic communication is established between the firing point, or place of the piece, and the two points occupied by the plane-table observers.

"During the firing of the present class, interesting observations were made with respect to the effect of wind on the flight of projectiles, and very important deductions made therefrom. Experiments were also made with improved sights for heavy ordnance, the result of which realized what was expected, and proved that fine and accurate fixtures for sighting purposes are as necessary for good firing with cannon as for small-arms, and generally that the work required of rifled pieces demands that they should be constructed with the same degree of accuracy as that given to modern small-arms. The object for which such pieces are intended, viz. great power and accuracy at long range, calls for an exactness and nicety of manipulation unknown to the days of smoothbore ordnance, when a pound or two of powder, or a degree or two of elevation more or less, were considered matters of but little moment. The crude methods of former times are as much out of place with rifled ordnance as would be the clumsy handling of the Brown Bess applied to the rifled musket of the present day.

"The records of last year's firing fully attest to what degree of accuracy firing with rifled cannon may be brought by a proper observance of the rules of marksmanship and gunnery.

DEPARTMENT OF ENGINEERING.

"This course embraces topographical and other military drawing; use of surveying and like instruments; field intrenchments; elements of permanent fortifications; military bridges; reconnaissances, and topography as applied to military requirements, together with so much of submarine mines as belongs to engineering.

"Instruction commences on September 1 (of the first year) and continues until December 22, when it is terminated by the examination in this subject.

DRAWING.

"The first thing taught is topographical drawing, as a necessary means for putting in an intelligible form the results of surveys and reconnaissances. It also gives facility in sketching the topographical features of a country in the manner hereinafter mentioned, and furthermore teaches the art of map-reading, an item of great importance to those engaged in actual campaign movements. Especial attention is given to the use and application of scales.

INSTRUMENTS.

"Drawing is followed by the study and practical use of the following instruments, viz. The railway transit; surveyor's compass; prismatic compass; surveyor's transit; transit theodolite; solar compass; transit with solar attachment; sextant and box sextant; telemeters and range finders; plane-table; reflecting level; Y level; graduated circle; aneroid barometer; theodolite and verniers.

"These instruments are put into the hands of the students, who, with the assistance of text-books, study their mechanism and familiarize themselves with their adjustments and the manner of using them. Particular attention is given to the use of verniers and to the method of reading different kinds of graduations. To perfect the students in handling the instruments, they (the students) are sent to perform actual work in the field; for which purpose they are generally arranged in pairs, each pair having some one of the instruments. In this manner they continue until all have had practice with each instrument. All observations, calculations, and plottings are recorded and constitute the reports of the officers on the particular work assigned them. These show for each if his work has been well done, and if he is proficient in the use of the instruments.

FIELD INTRENCHMENTS.

"Field intrenchments are next taken up, the subjects being given out to the students, and by them demonstrated by drawings which they make regardless of scale, but with due attention to proportion; the object being to produce, in a free, distinct, and forcible manner, a graphic representation of this class of engineering operations, as required in actual service, and to acquire readiness in the method of explaining to those executing such work the manner in which it is to be done. Everything in this branch is thus gone over by the student, and the drawings themselves are evidence as to his knowledge of the subject. The instructor questions each upon his work, and in this manner greater proficiency is secured than by the old method of blackboard recitations.

"The drawings of the class just graduated show with what industry and thoroughness this part of the course was pursued.

"For the purpose of teaching the method of applying the theoretical instruction laid down in text-books, and of making the students practically familiar with the responsible duties devolving upon commanders when planning the investment of places, a copy of the topo-

graphical map of Yorktown and its vicinity was furnished each member of the class. Upon this he was required to locate a line of intrenchments such as in his judgment would be required for an army besieging another holding that place. The officer submitted with his *projet* a brief explanation, giving his reasons for locating each part of his line, designating the number and location of the troops, the number and kind of guns, with the positions of batteries, and other data of like nature.

"This method of studying siege operations awakened the lieutenants to a train of practical thought not often indulged in by officers until brought to it by the exigencies of service, when such work often has to be done whether they are prepared for it or not. It is not difficult to perceive the advantages afforded by such instruction to those who may command or advise in future wars.

"During this part of the course, the students trace and profile, in full dimensions, the front of a bastioned field-work, which when laid out is ready for the employment of a brigade in digging and throwing up the work. Instruction thus practically given is not likely to be forgotten, and officers possessing such knowledge are masters of the situation when actual service requires such duty of them. War now, more than ever before, demands the employment of field intrenchments, and too high an estimate cannot be given to practical skill in such work.

MILITARY BRIDGES.

"This subject does not embrace the higher and more complicated system of bridge architecture, but is sufficiently comprehensive to include those methods for crossing streams most frequently used in campaigns, and also such expedients as may be resorted to upon occasions of emergency, and which are often found to be of vital value, especially to those upon raids, reconnaissances, and other similar service. Models have been constructed representing such devices and bridges, and these, together with text-books, afford ready means of comprehending the subject. Drawings of all these things are made in the manner observed for field entrenchments. Those of the present class are creditable in the highest degree.

SUBMARINE MINES.

"This subject naturally divides itself between the engineering and artillery courses. That belonging to the former embraces a study of the locality in which defensive torpedoes are to enter in conjunction

with shore defenses; the planning and laying out systems of mines, and connecting them electrically with such defenses, the manner of planting and mooring mines, and the various means employed for determining the position of an enemy's ship when approaching planted mines. All that relates to the construction, the charging, and the firing of mines, together with their electrical arrangements, belongs to the course of artillery, and will be mentioned in connection therewith.

" For want of proper text-books—now supplied by an elementary treatise—the present is the first class that has had the subject of mines. They took much interest in the subject, and for the purpose of giving their thoughts a practical trend, each member was given a copy of the Coast Survey chart of Hampton Roads, upon which he was required to lay down a plan for a system of mines co-operating with the land defenses for the security of that roadstead. Each officer accompanied his plan by a brief explanation of the system adopted. A very creditable start has thus been made towards diffusing a knowledge of this species of defence, so much relied upon for the protection of the numerous harbors of our coast, but of which little is known by those who will chiefly have to operate such mines in time of war.

RECONNAISSANCES.

" Since the extension of the course to two years, the classes—*i. e.* the three last—have been enabled to make extensive military surveys and reconnaissances of the surrounding country, particularly of the *Peninsula*, 55 miles in the direction toward Richmond.

" During October of the engineering year the class, with the engineering instructors, go into camp in the region of country to be reconnoitered and mapped. Horses are provided for the lieutenants with which to do the work.

" The work is laid out by the instructors, giving to each officer a certain field for his operations. The method pursued is that described in Artillery School Circular No. —.

" By this method all the topographical features of the country passed over are laid down in proper position to a suitable scale.

" One person is able, upon an average, to cover one square mile per hour, or about two miles of road, taking in one-fourth of a mile on each side. About three weeks are thus spent in camp. The work in the field being completed, the parts executed by the several officers are collated and put into one map by one of them, designated for the purpose.

"The accuracy with which the various parts connect attests the correctness of the work and the faithfulness of those executing it.

"The present class reconnoitered and mapped the country on the east side of York River, extending from Gloucester Point to the mouth of the Pamunkey River, making, with that executed by former classes, about 1000 square miles of work. This map, together with the one made of the *Peninsula* by former classes, would have been invaluable to the Army of the Potomac in the campaign of 1862, when knowledge of the country over which it was groping its way was confined almost entirely to the line of its pickets. Or, in default of such maps prepared beforehand, officers practically instructed in doing such work would have proved of the greatest service to those directing the movement of that army.

"The important part played by the topographical features of a country upon the operations of war makes it not only desirable but imperative that a reliable and ready method of procuring such knowledge should be at the disposal of a commander in the field. The omission of instruction to this end would be a glaring defect at any military school of application.

YORKTOWN SURVEY.

"In addition to the reconnaissance work just mentioned, the present class executed a topographical survey of Yorktown and its vicinity, and produced a map of exceeding accuracy, neatness and finish.

"This survey was made at the request of the Congressional Committee on the Yorktown Centennial, and was used by them in locating the various points of interest of that historic field, and in selecting the site for the Yorktown Monument. It also proved of great service in making preparation for the grand celebration held there last October.

PHOTOGRAPHY.

"Connected with the course of engineering, is so much of photography as instructs officers practically in the use of the camera and plates, and in printing from negatives and tracings, and in *fixing* the prints. Photography is now of such general application in the reproduction of maps, drawings, etc., as to require that a knowledge of it should be possessed by military men.

"The *dry* process, which is also taught, enables officers upon reconnaissance to carry with them, at but small inconvenience, a compact photographic apparatus, by means of which they can take almost in-

stantaneous views of the more important positions, and thus convey to a commander correct information of their observations.

"Photography has proved especially useful to the school in taking views of the various operations connected with the handling of artillery. Many of these have been reproduced to illustrate drill and other *circulars* intended to aid in instruction. It is also becoming useful in connection with photo-lithography, and reproduction of maps and drawings made by the students by that process.

PERMANENT FORTIFICATIONS.

"While the planning and construction of permanent works of defence belongs exclusively to the Corps of Engineers, their occupation and defence is intrusted to the artillery arm. It is therefore essential that officers of the latter branch of the service should possess a knowledge of their objects and capabilities. The elements of permanent works are, therefore, included in the course of instruction at the school, and belong to engineering. The study of them, taken from text-books, is supplemented by every-day observations upon the works at Fort Monroe and elsewhere.

ESSAYS.

"The course in engineering is completed by each officer writing an essay on some subject comprised in engineering. To the present class was given the "*Attack and defence of Fort Monroe*," certain conditions being laid down in the problem. Half of the class were assigned to the *attack*, the remainder to the *defence*. Some of the papers produced were able discussions of the subject, and all showed that the minds of the students had been awakened to originality of thought and brought squarely to the consideration of a class of subjects of great importance to artillery officers.

DEPARTMENT OF ARTILLERY.

"Mention has already been made of the firing practice which took place in July and August. This is followed by other practical out-of-door exercise, chiefly mechanical manœuvres, which take place daily, Saturdays and Sundays excepted, and continue throughout the entire period of two years. The course proper of artillery, however, begins on January 5 (first year) and continues until the 15th of the following September, commencing with the science of artillery, viz. Gunpowder

and other military explosives; construction of artillery; projectiles; fuses; determination of velocities and trajectories; inspection and care of ordnance and ordnance material, and use of defensive torpedoes.

"The method of instruction in these branches partakes necessarily largely of the recitation system, and includes the application of a considerable knowledge of mathematics. This, however, is relieved by a large amount of practical work judiciously intermingled with the theoretical.

CHEMICAL ANALYSIS.

"While engaged upon the subject of gunpowder and other explosives, the students, in sets of twos, are sent in rotation to the chemical laboratory, where they continue for about two weeks, analyzing different kinds of powder, employing both gravimetric and volumetric analysis. Report of the analysis in each case is made to the instructor, who questions the students upon their work, thus making them perfectly familiar with the subject. Much interest is manifested in this branch, and although officers may never be called upon in service to make or analyze powder, this study and practice makes them familiar with every property belonging to this compound, the very breath of life of modern warfare. Especially is a thorough knowledge of this branch necessary when it is remembered that the wonderful advancement made during the last few years in the power of artillery is due chiefly to improvements in powder and in adopting proper and special grades for specific pieces. No longer, as formerly, is *any* kind of powder used indiscriminately for all variety of ordnance. It is therefore necessary that an artillerist should have more than a mechanical knowledge of his profession to be equal to what is now required of him in this direction.

"Specimens of the different kinds of powder used in our service, as also many experimental varieties, showing progressive steps in the art of manufacture, are kept to aid in familiarizing the students with the subject, so that none may be at a loss when seeing a sample to determine its class, quality, and to what service and kind of piece adapted.

"The students are also taught the manufacture of nitro-glycerine and the preparation of its various compounds.

"In addition to this practice on explosives the course has been extended somewhat out of the artillery line to embrace the approximate analysis of flour and other components of the soldier's ration, employing such simple means as are generally to be found at military posts.

VELOCIMETERS.

"In a manner similar to the foregoing, the students are taken to the casemates where the instruments used for determining the velocity of projectiles are kept, viz. Schult's chronoscope, Benton's velocimeter, and the Boulongé chronograph.

"All of these instruments require the most delicate manipulation to obtain satisfactory results, and ample time is allowed for each student to make himself familiar with these machines. The operation of them requires the employment of electro-magnetism; the students are consequently taught electricity and made expert in the use of cells, batteries, galvanometers, rheostat, and the arrangement and testing of lines. Such instruction is furthermore required for the subject of submarine mines, hereafter to be mentioned.

DENSIMETER.

"In like manner instruction is given in the use of the Mallet mercury densimeter, an instrument, the invention of which has made possible the perfection to which the manufacture of gunpowder has been brought.

"A knowledge of these various instruments is a necessity to those who desire to fully comprehend the current literature of artillery, a familiarity with which is required of every well-informed officer of that arm.

"Students not engaged in laboratory work or with the foregoing instruments attend at the section room and receive instruction embracing descriptions of the principal types of ordnance of this and other countries; their mode of construction, breech firmatures, causes of weakness, and causes leading to the bursting of heavy guns; the physical properties of gun metals; the manufacture of rifle projectiles; description and use of the Rodman testing-machine; inspection, care, and preservation of ordnance, together with a vast amount of other matter belonging to the subject of ordnance and gunnery.

"In pursuing this course, the obsolete matter contained in the usual text-books is omitted, and recourse had to that which is up with the times, a certain part of which is obtained from the valuable *Notes* published from time to time by the Ordnance Department. In this manner instruction keeps pace with progress in the science and art of artillery.

SUBMARINE MINES.

"A large part of this important subject belongs naturally to the artillery course, but for lack of *cases* and other necessary appliances nothing has been done in a practical way, excepting a few experiments on a small scale. This branch of defensive warfare has of late years grown into great importance, and is supposed to be the most efficient means for securing the cities of our seaboard from the grasp of an enemy.

ARTILLERY DRILLS.

"The out-of-door practical exercises in the course of artillery consist in the *service* of each kind of piece in use in the land service of the United States, firing practice and mechanical manœuvres with the same, and laying platforms. Mention has already been made of the firing exercises. The *service* of the piece is thoroughly taught. The mechanical manœuvres occupy most of the time, and embrace every operation required in mounting, dismounting, and moving heavy ordnance, including a knowledge of the construction and application of the various machines, such as gins, derricks, hydraulic jacks, sling-carts, gun-lifts, etc. The instructor in artillery drills keeps a roster of the officers, assuring to each one ample opportunity for performing each and every operation laid down in the Manual of Heavy Artillery. Owing to the scarcity of men, detachments cannot be made up for all the officers at one time; surplus officers are therefore assigned during the drill time to some other duty. Drill exercises continue daily throughout the entire course, Saturdays and Sundays excepted, and, with the exception of a small portion of time given to infantry, are devoted entirely to artillery.

INFANTRY.

"Practical instruction in this includes the school of the soldier, school of the company, and school of the battalion, together with target practice, bayonet exercise, and *forms* and *ceremonies*.

"Recitation in infantry tactics, below brigade movements, are omitted, for the reason that such exercises are taught practically, and each officer studies to make himself competent in the practice. The same is true in regard to artillery tactics. Formerly, a large amount of valuable time was expended in going over tactics, the results being no more advantageous than the present method.

*DEPARTMENT OF MILITARY ART AND SCIENCE.**

"The next subject in order is the above, instruction in which commences September 1 of the second year, and continues until the 15th of the following January.

"The course began this year with infantry tactics, taking the school of the brigade, division, and corps, in which many practical problems were given out, involving the most expeditious way of changing formations and positions; camping, marches, and certain of the *ceremonies* were also included, after which 'Hamley's Operations of War' was taken up, the whole work being included. This portion of the course was interspersed with lectures on campaigns of our late war, illustrative of the principles enunciated by the author. Among such was Vicksburg, which, divided into epochs, gave three long lectures, illustrating the principles of interposing an army between the divided portions of another, and that of 'total interception.' Others were as follows:

"Jackson's Valley Campaign, 1862.

"Hood's and Forrest's operations on Sherman's rear, 1864 (two lectures).

"Campaign and battle of Nashville.

"The Antietam campaign (two lectures).

"For the purpose of elucidating thoroughly these lectures, maps in detail were prepared on the blackboards, and notes were taken by the students. The following day the subject was reviewed, the officers questioned thereon, and every principle of strategy or grand tactics fully discussed, thus bringing the application of these principles down to our own country and military history.

"After this came lectures on 'advanced guard' and 'outpost duty'—a lecture on each, according to the latest developments and most approved European methods. In order to discuss and illustrate the general formations in battle of the three arms, separate and united, including the space occupied by each in different formations, and the time required in passing over distances at different gaits, together with the phases of a great battle extending over a large scope of country and great variety of ground, the battle-field of Bull Run (campaign of 1862) was taken by way of example. A map upon a

* It is to this part of the course that particular attention is invited. There can be no doubt that the science of war, as taught in the Military Schools, has become an essential part of the education of the naval officer of to-day.

large scale was painted with oil, in conventional colors, of the country embracing the operations of the contending armies on that field. Upon this map the different positions were indicated with colored crayons, following the various phases of that battle.

"To illustrate the principles of outpost service the officers were required to occupy a certain extent of ground with an outpost line, and give reasons for the posting of each guard, sentinel, and picket.

EXAMINATIONS.

. . . "The pamphlet on 'Infantry Tactics in Battle,' by Sir Lemley Graham, reprinted at the school, was studied with a view to informing the officers upon the systems now in vogue among the principal European nations. Next followed a lecture on the 'outlines of military geography,' after which each officer was given one of the States, or some portion of our country, of which to compile the military geography, setting forth such physical features of the region as would have importance in military operations; railroads and other means of communication; military resources, such as population, agricultural and mechanical products, and generally all matters that would enter as a factor in the military capabilities of the country. This practice awakened much originality of thought and research.

"Practical problems, some eight or ten in number, were now given out, taking two each day. These problems involved the planning of campaigns, having certain forces and conditions given on each side. The maps used for these were photographs from the War Department campaign maps, and familiar theatres of operations were usually taken. The problems increased progressively in magnitude, from the operations of a small force manœuvring about Hampton, to those of several corps constituting an army, and were given to two officers to work out together. The following day they brought their notes, with their map, and the matter was gone over in open discussion, thus obtaining an interchange of ideas. The especial value of such practice is to teach officers how to think for themselves.

"The subjects for *essays* are given out October 1, to be handed in at the end of the course, thereby giving ample time for research. In writing the essays, the form prescribed in General Orders No. 18, C. S., Artillery School, was followed as far as practicable.

"The following were the subjects given to the present class:

1. Review of Wellington's campaign in the Peninsula.
2. Sheridan's campaign in the Valley and around Petersburg.

3. The military organization and administration of the great powers of Europe.

4. The use, development, and influence of the telegraph and railroads in warfare.

5. Plan for the organization, instruction, and care of an army corps, in camp and on the march.

6. Military resources of Canada, and plan of operations, strength, and organization of an army necessary to prosecute a successful invasion of that country.

7. Campaigns of Gustavus Adolphus in Germany during the Thirty Years' War, particularly the battle of Leipsic, September 7, 1631.

8. Organization, development, and use of cavalry in the American civil war.

9. Review of the Seven weeks' war between Prussia and Austria, 1866.

10. Review of the Russo-Turkish war, 1878.

11. Review of the second Bull Run campaign.

12. Influence of the breech-loader and other modern fire-arms.

13. The Wilderness campaign, 1864.

14. Bragg's campaign in Kentucky and Tennessee, 1862.

15. The advance on, and investment of, Metz by the Prussians.

16. Review of the most noted battles of Frederick the Great.

17. Review of Marlborough's battles.

"In preparing their essays, the students avail themselves of the school library.

"At the appointed time the essays are turned in to the instructor, who gives them a critical examination, and marks each according to its merits. These marks have the value of three ordinary recitations, and count in estimating general merit. Subsequently they are publicly read, each officer reading his own, and illustrating, when necessary, the subject by a blackboard map. Upon an average, each essay consumes about three-fourths of an hour in reading, and two are generally read in one afternoon. Inclement afternoons, when out-of-door exercises cannot be had, are utilized for these readings.

"The course in military art and science closes on the 15th of January, with examination.

"The following is a list of the questions given to the present class:

FIRST DAY.

1. What are "orders of battle" defined to be, and when is an order well chosen?

2. What are the disadvantages of the salient order of battle as illustrated at the battle of Prague?

3. What was the order of battle at Nashville of the Union Army?

4. What should be the position of the line of battle with reference to the line of communication?

5. In taking up a defensive line, or when attacked while manœuvring, what conditions of position should be sought?

6. What grand principles should be observed in the conduct of an attack?

7. What principles would govern in selecting points of attack?

8. What should be the composition, strength, and order of march of an advance guard?

9. What are "outposts," the strength of, how computed, their distance from the main body, how disposed, and where supports and reserves?

10. Give the principles of modern tactics of infantry in battle, assuming a battalion of 4 companies of 100 men each for illustration.

11. What should be the conduct of a pursuit?

12. What are some of the changes in contemporary tactics with regard to artillery and its employment in battle?

SECOND DAY.

1. What is the general object of strategy, and what are the kinds of advantage to be attained by it?

2. What are the particular objects of strategical movements?

3. What power does the "offensive" give, and what is the "initiative"?

4. What strategical principle was illustrated in the Ulm campaign (1805)?

5. What strategical principle was illustrated by the Italian campaign (1796)?

6. What strategical principles were illustrated by the Vicksburg campaign?

7. What are the different ways in which a containing force may be employed? with examples.

8. What is military geography, and what advantage is a knowledge of it to a general operating in his own or an enemy's country?

9. What was the nature and influence of the "obstacles" in Jackson's Valley campaign in 1862?

10. What strategical and tactical principles must be employed in crossing a river held by an enemy?

DEPARTMENT OF LAW AND MILITARY ADMINISTRATION.

"This is the next and last course, beginning January 15 and ending April 15. This course embraces military law and practice of courts martial; international law and laws of war; constitutional law and Constitution of the United States; regulations and customs of service of the United States Army; and forms of official papers, correspondence, orders, and records pertaining to its administration.

"It will be manifest to any intelligent person that the subjects of this course have been carefully selected, and with a view to grounding officers in the fundamental principles of law and government especially as applied to our own country and to the workings of the military organization of the United States. It aims at something higher than making mere courts-martial pettifoggers of them.

"Officers in the military service, more than any other class of citizens, are called upon to exercise functions demanding legal judgment, and frequently to act with decision and promptness upon questions of a high and critical order. It is therefore important that they should be so informed upon the sound principles of law and government as to know how to act correctly.

"The following list comprises the questions given out to the present class:

FIRST DAY.

International Law.

1. State briefly the nature and sources of international law.
2. What is a sovereign State?
3. How may sovereignty be acquired?
4. Give the reasons which justify pacific interference by a State in the internal affairs of another State.
5. What are royal honors?
6. What is the extent of maritime territory?
7. What is the extent of the inviolability of public ministers?
8. What is the effect on individuals of a declaration of war?
9. Duty of a State to support its troops?
10. What implements of war may be lawfully used against an enemy?
11. What is the right of asylum, and the distinction in regard to troops?
12. What is the right of visitation and search?

SECOND DAY.

Constitutional Law.

1. Give some of the causes which led to the rejection of the Articles of Confederation by the people of the United States and the adoption of the Constitution.
2. For what purpose was the Constitution established?
3. Of what is the Senate of the United States composed, and into what classes is it divided?
4. Give the mode of electing the President and Vice-President of the United States.
5. Give the form of proceeding on bills and joint resolutions.
6. State the powers of Congress in regard to taxes, to commerce, to money, the transmission of mails, and in regard to war.
7. Give the restrictions on the powers of Congress in regard to the writ of habeas corpus, bills of attainder, and taxes.
8. Give the constitutional restrictions on the powers of the several States.
9. In what manner is the security of persons in their houses, papers, and effects secured by the Constitution?
10. What rights are secured to persons charged with crime?
11. Who are citizens of the United States?
12. How does the Constitution prohibit slavery?

THIRD DAY.

Military Law.

1. From what sources is the authority to appoint courts-martial derived?
2. Who may appoint a general court-martial?
3. Give the various courts-martial, and the number of members in each.
4. What is a military charge?
5. What is necessary to be stated in the specification?
6. What is a challenge, and how is a question of challenge decided?
7. What is the arraignment of a prisoner, and at what stage of the proceedings does it take place?
8. Give the various pleas which may be made.
9. When may depositions be read in evidence?
10. Give the order in which witnesses are called and examined.
11. Give the mode of procedure when the proceedings of a court-martial are returned for revision.
12. What is evidence? Why is hearsay evidence not receivable?

"The entire course of instruction completed, each lieutenant who has successfully passed through it receives from the staff a certificate of proficiency—an instrument, on parchment, similar to a diploma.

"In addition to the certificates thus awarded, the staff makes a report to the War Department of the special fitness of each lieutenant for the various commands and duties to which he may be called, thus making a record by which it is easy for the government to make proper selection of officers when special fitness is required.

"The course, take it all in all, is certainly well adapted to the objects for which the school is maintained, and embraces as much as can possibly be gone over in a proper manner during the two years allowed for it. The method of instruction is such as to secure interest and attention from every officer under instruction, and it matters not what advantages he may have had, either as a veteran of the late war or as a fresh graduate from the Military Academy, or from any other institution, he here has opportunities of adding to his stock of knowledge nowhere else to be found in this country; or, on the other hand, however ill prepared, stupid, or indifferent he may be, it is impossible for him to pass two years at the school without having some of its benefits adhere to him."

The foregoing details have been given for the purpose of showing how thorough and comprehensive the post-graduate course of the army is. It makes us wish more and more, as we read it, that we had a similar course for the navy.

UNITED STATES INFANTRY AND CAVALRY SCHOOL, FORT LEAVENWORTH, KANSAS.

There is abundant evidence to show that the Artillery School has accomplished a great deal of good for the army; so much so, indeed, that a similar school has been organized and is now in successful operation at Fort Leavenworth.

General Order No. 8, U. S. Army Headquarters, declares the "School of Application for Cavalry and Infantry to be established." Colonel Otis, by the terms of the order, is placed in command of the school, and is charged with the practical instruction of every soldier and officer of his command in everything which pertains to army organization, tactics, discipline, equipment, drill, care of men, care of horses, public property, accountability, etc.; and, generally, of every thing which is provided for in Army Regulations—these must be his first care. The second is the theoretical instruction which ought to precede a commission. This consists mostly of elementary instruction intended for enlisted men; and the third is the "Science and practice of war so far as they can be acquired from books."

"The subjects for the school are the lieutenants belonging to the companies which compose the garrison and those specially detailed from the regiments, making about fifty in all.

"These will, on reporting, be examined by the Staff of the School, and divided into two classes, the first, only, requiring the higher course as defined above; the second the whole course of two years."

For the First Class the text-books used are:

Mahan's Outposts.
Myer's Signalling.
Mahan's (Wheeler's) Field Fortifications.
Woolsey's International Law and the Laws of War.
Ives' Military Law.
Operations of War. (Hamley.)

"The Lessons of War as taught by the Great Masters," by Colonel France J. Soady.

"Lectures by professors and essays prepared by the students from general reading.

"Practical instruction in surveying and reconnoitering by itineraries and field notes as prescribed for the use of the Army.

"The instructors are required to keep daily notes of application and progress, and about the 1st of January of each year a public

examination takes place, at which the classes are arranged according to general merit, and special mention made of each officer who deserves it, a report of which will also be made to the Adjutant-General of the Army for publication, and such use as may hereafter be determined."

This last clause suggests for the Navy an idea for a comprehensive system of promotion, beginning with the lower grades and giving due weight to the holding of post-graduate certificates.

We come now to the

ENGINEER POST AND DEPOT OF WILLETS POINT, NEW YORK HARBOR.

"This post is the School of Application for the Engineer branch of the army, where officers newly assigned to the Corps of Engineers complete the purely theoretical course of instruction received at West Point, and where the enlisted men of the Battalion are trained in submarine mining, pontoniering, sapping and mining, military-map making, and other duties pertaining to this arm of the service.

"The depot contains the more delicate parts of the submarine mining material purchased for the defence of the coast; the bridge equipage of the army; the engineer trains for field service; the astronomical, geodetic, and surveying instruments in store for the general use of the Corps of Engineers. The enlisted men of the Battalion guard and care for all this property.

"The School of Application for officers has made steady progress during the past year (1882). It includes not only the strictly military branches of the engineering profession, but many civil branches as well—such as practical astronomy, meteorology, and barometric hypsometry, surveys, tidal and current measurements, electricity in its practical applications, and other similar work involving familiarity with the use and the handling of delicate instruments and with refined modern methods. This School is the only place in this country where close and systematic study is given to the various problems involved in submarine mining for coast and harbor defence. A class of two artillery officers has been permitted to take this course during the past season with a view to qualifying for detail in this branch of the Engineering service; and all the young officers assigned to the Corps of Engineers are now required to make themselves thoroughly familiar

with the subject before going to other duty." See Report of Chief of Engineers, U. S. Army, 1882, p. 62.

In the report of the year previous, and under the same head, it is remarked that "the course of instruction at West Point is, from the nature of the case, limited to the theoretical study of most of these branches; and the tour of duty at Willets Point not only accustoms the recent graduates to service with troops, but also renders them expert in the handling and use of instruments and in the practical application of their knowledge learned from books."

Hence we see that there are three Schools of Application in the Army, at each of which there is a thorough course to prepare the officers and enlisted men for the great business of their lives—the practical operations of war.

This is just what we need for the Navy. The naval officer, not less than the army officer, should possess a knowledge of the science and practice of war, "so far as it can be acquired from books."

It has been frequently observed that steam enables a fleet to perform military movements with the same certainty and precision that can be predicated of troops operating on land. And although it is commonly remarked that the days of great fleet fights are past, yet it is quite certain that when several ships of war are assembled together there must be some recognized system of tactics, conducted by a carefully devised system of signals; and where two belligerent squadrons meet there must, or should be, some recognized manner of forming and going into battle, or of receiving an attack. It is not reasonable to suppose that this country is never to have another vessel of war of sufficient military power to take her place in the line of battle; nor is it to be presumed that we are to have our entire Navy composed of nothing but independent cruisers and fast "commerce destroyers." We must at some time have fighting ships, and those ships must be assembled for exercise preparatory to battle, and that exercise will require a well-digested system of steam tactics devised with special reference to battle. It is time this matter should be taken up and made the subject of careful study by officers of all grades; for it cannot be assumed for one moment that the elementary tactics of the late Commodore Parker, good as the fundamental idea on which they are based undoubtedly is, comprises the whole art of naval warfare.

But there is another branch of his profession which the naval officer should study: he should not only know how to fight his own ship, and how to form and carry several ships into action, but having a certain force at his disposal, he should know where to place it that it may do the most good. In other words, he should have some idea of the principles of strategy, that he may be able to comprehend the strong points within the field of operations, and either hold them or prevent an enemy from holding them. A squadron (for a very plain illustration), decoyed into the pursuit of a hostile force through the West Indies, would be ill requited on returning, even with a few prizes, to find Key West in possession of the enemy. Such stratagems are not uncommon in war.

It is the part of the naval student to prepare himself by study and reflection for these higher duties of his profession; and the only way to do that is to study the science of war as it is taught at our military schools, and then to apply the principles to the military operations conducted at sea. He should be led into a philosophic study of naval history, that he may be enabled to examine the great naval battles of the world with the cold eye of professional criticism, and to recognize where the principles of the science have been illustrated, or where a disregard for the accepted rules of the art of war has led to defeat and disaster. Such studies might well occupy the very best thoughts of the naval officer, for they belong to the very highest branch of his profession.

In addition to the study of war we must add a higher course in ordnance; a course in international law, the higher mathematics, languages, astronomy and hydrography.

As for the location of such a school or college, there can be no doubt that Coasters Harbor Island, where there is already a suitable building, affords the greatest advantages. The facilities for practice in submarine work, the proximity of the Torpedo Station, the advantages the place offers for the establishment of ranges for great gun and small-arm firing, and the fact that here we possess all the accessories ready for the immediate establishment of such a school without the expenditure of a single penny—all point to it as the most feasible and at the same time the most desirable place for the inauguration of a scheme for the higher education of our naval officers.

With all my ardent desire for the advancement of my profession, I have not the time to prepare such a paper on the subject under consideration as I should like or as its great importance demands. I

have said enough, however, to indicate what is being done in the army for the professional improvement of officers, and what reason points out that we should do for the officers of the navy. The plan is perfectly practicable, and, from what we have seen cropping out on all sides of the desire of our officers for higher and broader fields of study, I am persuaded it would prove a popular and successful undertaking.

There is one view of this subject well worthy of consideration: Would not a post-graduate course have the effect of modifying the curriculum of the Naval Academy by the transfer, to a later period, of studies better suited to more matured minds? And if the curriculum of the Academy be thus relieved, could not more time be devoted to the remaining studies, making instruction in them all the more thorough?

With these hasty remarks, I respectfully submit to the intelligent consideration of the members of the Institute the question of establishing a post-graduate course for the study of the Science of War, Ordnance, and International Law, and such cognate branches of the three grand divisions as may be determined upon.

NAVAL INSTITUTE, ANNAPOLIS, MD.

NAVAL INTELLIGENCE.*

By Ensign Charles C. Rogers, U. S. N.

That *intelligence* is not used here in the sense of quick understanding, but in that of information, is a fact sufficiently understood. Worcester defines the word as "acquired knowledge; news; account of things distant or secret; communicated information." An office of intelligence, abstractly considered, is therefore an office from which these several forms of information can be obtained. With reference to an Intelligence Branch of either of the services, each of these definitions is especially appropriate. "Acquired knowledge" is applicable as that kind of information which can be derived from standard professional works of all nations; "news" as information that can be culled from the daily and weekly journals and service literature of every country; "account of things distant or secret" is found especially in the reports of military and naval attachés and other agents; while "communicated information" is contained in reports of officers on duty at home or on foreign stations.

With these facts in our memory it will be understood that the special duties of an office of Naval Intelligence are:

Firstly, the collection, sifting, and arrangement of all information required by governments and naval authorities to enable them to take such measures in peace as will insure the rapid commencement and vigorous prosecution of any war, whether at home or abroad.

* In the preparation of this article the writer has consulted the following publications: "Duties of the General Staff," by Major-General Von Schellendorf, at present Minister of War at Berlin; "The Intelligence Duties of the Staff Abroad and at Home," by Major C. B. Brackenbury, R. A.; "Naval Intelligence and Protection of Commerce in War," and "Defense of Great and Greater Britain," by Captain J. C. R. Colomb, R. N.; "Armies of Asia and Europe," by Major-General Emory Upton, U. S. A., and histories of the Civil War in the United States.

Secondly, the diffusion of necessary or useful naval information through the navy and the country during peace or war.

The machinery of war becomes more complicated, more costly, and swifter in its work in proportion to the advancement of civilization. The necessity for readiness becomes every day more absolute, while the means for obtaining the latest information increase with the growth of national armaments and with those helps to swift action—steamers, railways, and telegraphs. The information required for the successful and economical prosecution of war is obtained with comparatively little difficulty during peace, and should be ready in a concentrated form when war breaks out.

To quote the Prize Essayist* of last year, "The attention of line officers of the navy should be directed to the solution of the actual problems of modern warfare. They should study the turning of ships at full speed to ram or to avoid being rammed by another vessel, the working of naval batteries so that their fire may be made available at full range against an enemy in motion, the mounting of guns to secure an all-round fire without exposing crews to the deadly fire of machine guns and small arms, the disposition of naval forces for the attack or defence of particular harbors, the control of a group of torpedo boats in an attack, and the defence of vessels from torpedo attacks where Whitehead's or other formidable weapons are used. . . . The naval brigades which assisted in the defence of Sebastopol and Paris, and made long and arduous campaigns in South Africa and Egypt, have demonstrated the errors contained in the old and narrow views of the usefulness of seamen. The necessity for preserving proper precautions in landing or marching in an enemy's country has also been increased by the changes in arms and methods. Men are often landed in peace as well as in war, and to be prepared for all contingencies officers should learn how to make a reconnaissance, to conduct a march or to guard a post in a hostile country."

There is a tendency to neglect these subjects, "and to accept an imitation of the seamen found in our ships, at some traditional or imaginary period of the past, as the standard article. Marlin-spike seamanship and a sailor-like bearing are matters of some real importance, but they will not make up for obstinate ignorance of everything relating to modern naval warfare. Looking at military requirements alone, a certain amount of educated intelligence will be essential to the men who are to handle such complicated engines of war as a rifled

* Lieutenant Carlos G. Calkins, U. S. N.

gun of large calibre or a modern torpedo. . . . . Discipline and responsibility do indeed develop some of the most essential qualities of the fighting man, when applied to good material. But the conditions of modern warfare—especially of naval warfare—are so complex and so subject to change that constant mental training is needed to enable officers to anticipate and prepare for the contingencies of attack and defence. The necessary work of the naval service can very readily be expanded into a vast system of routine for peace purposes which must obstruct every attempt to prepare for war."

In other words, the study of every officer should be the science of naval warfare, and his watchword "preparation for battle," for war is his profession. If such be the aim of the personnel of a navy, the information that should be published by an Intelligence Office would contribute greatly to that end.

A more thorough comprehension of this subject will be obtained by a glance at the duties and scope of the Intelligence Branches of the European services, since several of them were established nearly a century ago. But before proceeding directly to this study, the significance of the terms "Staff" and "General Staff" should be understood, since the Intelligence Branch is composed of officers of the latter.

It has been acknowledged always that success in war depends to a great extent upon a thorough knowledge of the enemy's country, strength, resources, and system of organization. As the science of war has advanced, it has been realized that a General commanding a large body of troops can not encumber himself with details, though their consideration and proper order may be often of the greatest importance. Assistants, therefore, have become necessary. These assistants constitute his staff. But with the numerical increase of military strength, the increased interior development of armies, and the more rapid transit and quicker communication, it has been found that a special corps of trained officers is necessary, not only to convert the ideas of the Commander-in-Chief into orders and convey them to the troops, but more especially to work out all the necessary matters of detail, and thus relieve the mind of the General from much unnecessary trouble. This corps constitutes the General Staff, and is now an essential part of modern military organizations.

As long as armies were small and their movements planned on one general model, the want of General Staff Officers was scarcely felt. The plan determined on by the leader generally contained the details

of execution; and but few principles were necessary to secure, in the way that was intended, the camping, marching, and deployment of a force on the field. A departure from the accepted forms presupposed a special arrangement that was intended to surprise and act decisively, but which could be initiated by only the General himself. This state of affairs, however, no longer exists. The great strength of armies, with their formations and facilities for transportation and communication, not only require, but also admit of every kind of variation, and make an immense variety of detail necessary for the execution of plans arising from situations that are even apparently similar. These and other causes incident to military science and war have expanded the duties of the General Staff in time of hostilities from mere surveys and reconnoitres to the following general heads of work and study:

1. Working out of all arrangements for the quartering, marching, and fighting of troops, according to the varying conditions of the military situation.

2. Communicating the necessary orders, either verbally or in writing, at the right time and in sufficient detail.

3. Keeping up the fighting condition of the troops and being constantly informed of their condition in every respect.

4. Obtaining, collecting and working out in order all materials that concern the nature and military features of the theatre of war. Procuring maps.

5. Collecting and estimating the value of information received concerning the enemy's forces and reporting on the same to the higher military authorities.

6. Charge of day books, publishing reports on engagements, and collection of important materials, to form afterwards a history of the war.

7. Special duties; reconnaissances.

The peace duties of the General Staff should prepare it for the duties of war; consequently the officers belonging to it have to work out all details of mobilization, marching, stationing, manœuvres, railways and telegraphs.

With this review of the work of the General Staff in war and in peace, let us trace the evolution of the responsibilities and duties that fall to it, and especially to the "Great General Staff," a body of General Staff officers not attached to the troops, and constituting the Intelligence Branch, since it is entrusted, under the immediate direction of the

Chief of the General Staff, with the preparation of extended operations through a knowledge and comparison of foreign military administrations, with the study of the theatres of war, with the preparation of maps, and with the promotion of military science and history.

The Prussian "Great General Staff" shall be the first to engage our attention, because having existed in its present form since 1816, those of other countries have been formed on its model, though with slight modifications.

Records of officers employed apart from regimental duty are found first in the Brandenburg (afterwards the Prussian) army under the direction of the Great Elector in the year 1655. There were twenty-seven officers on the General Staff in 1657, forty-six in 1673, twenty-three in 1741, nineteen in 1791, and thirty in 1796. During this period of one and one-half centuries, these officers were employed in surveying, engineering, reconnoitring camps and positions, and in finding and establishing roads for the movement of troops. New functions in this branch were created during the Seven Years War, which were expanded gradually so as to include in 1801 the collection of useful information and keeping a journal of operations. In summer the officers were employed in travelling, surveying and reconnoitring ground; and in winter these materials were put together and worked out. In 1803, the General Staff was divided into three corps, charged respectively with working out the eastern, southern and western theatres of war, together with the countries lying adjacent. These latter formed the permanent duties of the Staff; its casual work consisted of ordinary military subjects and literature, as well as of the most careful solution of all the probable cases of war in which the State could be involved under various suppositions. Officers were expected to make themselves familiar with all military positions at all remarkable in Prussian territory, both from a defensive and offensive point of view. The tours rendered necessary by these requirements were to be used for collecting information of every kind, which was to be kept up to date by constant reference to the civil authorities. In 1806 the summer tours were reduced to three months (partly for the sake of economy), and were to comprise foreign countries, "provided these might possibly form a theatre of operations for a Prussian army at any future time."

In the campaign of 1812 against Russia there were twenty General Staff officers of all ranks, besides nine Adjutants, in the Prussian Auxiliary Corps of 21,000 men. The wars of 1813–14 brought an

increase to the Staff, which after the Second Peace of Paris—in 1816—was consolidated, so that one portion remained in Berlin under its own special chief as the Great General Staff or Intelligence Branch, while the other part was distributed as the "Army General Staff" or Intelligence Officers among the army corps and divisional commands, the special duty of the former being to obtain information from all sources, and that of the latter to report upon all military matters in Prussian territory. In 1824, the peace establishment of the General Staff was 45, and the war establishment 101 officers. In 1853, the peace footing was fixed at 64 officers, and in 1867 at 119, which number remained until the declaration of war in 1870. Fresh demands were made in this war for an increase, and in 1875, after the amalgamation of the Ducal forces with the Prussian army, the number of the General Staff was fixed at 147 officers.

Of this number 72 belong to the General Staff of the troops, and 74 to the Great General Staff at Berlin, not including the Chief of the General Staff, who is Chief of both branches.

The general duties of the Great General Staff, or Intelligence Branch, are to collect information concerning the organization, tactics, and armament of foreign armies, the present and projected lines of railway and other lines of communication in foreign countries, to prepare plans of campaign, and to arrange all of the details for the mobilization, movements and concentration of troops in different theatres of war, either within or exterior to the empire. At its head is Count Von Moltke. He and his subordinates have nothing to do with the War Office except to supply it with any information it may require. Nor have they anything to do with the troops except the railway battalion, a sort of nucleus for railway studies in peace. The officers of this staff, however, are divided into two classes:

1st. The Active Staff, liable to service with corps and divisions in their turn.

2d. The accessory establishment (Neben État), consisting of officers distinguished for special scientific acquirements, and employed permanently at Berlin.

The first important fact is that all their labors are directed to one end—preparation for war—and that so thoroughly that there is nothing left unprepared when the time of trial comes.

During peace the duties are transacted under the immediate direction of Count Von Moltke, in bureaux and sections as follows:

1. The *Central Bureau*, charged with all matters relating to the

personnel of the Staff, the Survey, War Academy, and the Railway Regiment. It is presided over by the first adjutant of the Chief of Staff, who has the rank of Colonel.

2. The *Three Sections*. The duty of the Three Sections is to collect from all available sources the latest information concerning the organization, tactics, armament and mobilization of foreign armies, and to keep up to date systematized information concerning them. They are also bound to issue periodical descriptions of those armies for the use of the General Staff.

The First Section has charge of the Eastern Theatre of War, comprising Austria, Russia, Norway and Sweden, the Turkish Empire, Greece and Asia.

The Second Section has charge of the Central Theatre of War, comprising Denmark, Germany, Italy and Switzerland.

The Third Section has charge of the Western Theatre of War, comprising Holland, Belgium, France, Spain, Portugal, England and America.

3. The *Railway Section*, which works out instructions for the transport of troops and munitions of war, and presents plans for the transport of the German forces under different suppositions, so that the army may be concentrated, in the event of war, with the greatest possible speed upon any point likely to be threatened; it examines, also, all projects for new railways. These duties are not difficult to perform, since the section collects and arranges systematically all information on railways at home and abroad, especially with regard to their capacity for carrying troops.

4. The *Military History Section* devotes itself to the accumulation and arrangement of historical records and prepares histories of the great wars. The practical value of the study of military history must be apparent to every one.

5. The *Geographical and Statistical Section* collects and arranges all information of military value bearing on the topography and statistics of foreign nations, as well as the statistics of Germany. It studies all European powers exhaustively, while non-European nations are treated in less detail. It is also charged with the preparation of foreign military maps.

6. The *Topographical Section* carries out the survey of the country with special regard to military requirements, works out the details and prepares the maps.

7. The *Map Room*. Here are stored the original surveys and a

quantity of maps for distribution. This section registers all map work produced by the General Staff, and is in charge of the financial business generally.

All the information obtained by these sections is systematically arranged and made ready for use, so that in peace, the Intelligence Office is prepared to answer all questions put to it. It receives besides a large amount of secret intelligence, even during peace. At the beginning of each year the chiefs of sections report to Count Moltke what points in the information under their respective charges require addition or elucidation. Acting on their reports, officers are ordered to travel, being given definite instructions as to the information required and the day on which it must be furnished. These reports are sent to the Intelligence Office.

When war is declared the main part of the Great General Staff joins the army, the officers forming the Royal Headquarter Staff and the Staff of Army Corps. The principal Intelligence Office, however, remains in Berlin and uses all means of getting information. An Intelligence Office is formed also at the headquarters of each corps under the superintendence of the Chief of the Staff; these minor intelligence offices are all in communication with the chief office at Berlin, and thus any information reported is, by means of the telegraph, made instantaneously useful to all.

Publication is considered to be one of the special duties of the staff; a constant stream of information thus flows from the Great General Staff to the army and country.

Germany being always and absolutely ready, can never be caught unawares. In 1866, Prussian armies numbering 220,000 men were placed on the frontiers of Saxony and Silesia in a fortnight. In his valuable report entitled "The Armies of Asia and Europe," Brevet Major-General Emory Upton calls the attention of our Government to the work performed by the German staff, and especially to the plans of campaigns prepared in case of war with France. He says, "That these plans of campaigns were based on no guess-work we have ample proof in the fact that the able officer in charge of the section for collecting military statistics in reference to France reported 250,000 men as the largest force she could assemble on her frontier within two weeks after a declaration of war. The exactness of this estimate, confirmed by subsequent events, enabled the famous Chief of Staff, General von Moltke, to make all of his preparations." At the critical moment, Germany, taken by surprise, mobilized her

enormous army in nine days, and had on the frontier in eight days more, nearly 400,000 fighting men and 1200 guns; and in her next war the period of concentration will probably be shorter still.

The General Staff of Russia owes its origin to Peter the Great. As early as the reign of Catherine the Second, its special duty was to collect, in peace, intelligence concerning countries lying on the frontier, and in war to report on the situations of all divisions and columns, indicating the roads to them, and, at the same time, accompanying columns and detachments.

In 1874 its detail comprised 18 Generals, 52 Lieutenant-Generals, 71 Major-Generals, 196 Colonels, 55 Lieutenant-Colonels, 51 Captains, and 12 Staff-Captains, a total of 455 officers.

The *Chief Staff* of Russia corresponds to the Great General Staff of Germany. It is, however, a branch of the War Office. A section of this staff, called the Committee on Military Studies, more properly constitutes the Intelligence Branch. It directs the scientific work of the General Staff and the Topographical Corps, promotes scientific training in the army, collects information on the military capabilities of Russia and all foreign countries, keeps the library of the Chief Staff complete, superintends the course of instruction in the Nicolas Academy and the Topographical School, works out all questions raised by the Committee, considers the reports sent in by military agents abroad, and publishes military papers and journals. The President of the Committee is the Chief of the Chief Staff.

The whole of the Austrian Staff, whether at headquarters or with the troops, is considered available for intelligence work and is employed upon it.

The department corresponding to the Prussian Great General Staff was organized in 1871, and is divided into six intelligence divisions, requiring a permanent staff of 70 officers besides a large force of clerks.

These divisions are as follows:

1. The *Director's Division*, which conducts the correspondence, acts as a registry, and deals with personal questions and staff regulations. An extra number of officers are attached to it, who are employed in reading and commenting upon reports that have been sent in.

2. The Office for Military Topographical Intelligence concerning the Austrian Empire.

3. The Office for Topographical Intelligence of Foreign Countries.

The same system is pursued in collecting the information for these two offices. The Empire is divided into seven fields of operation, and the other countries of Europe, especially, into four theatres of war. The information is brought together, arranged on two similar principles and printed. It comprises a general description of the fields of operation and theatres of war, giving the peculiarities of countries, their topography, wealth, inhabitants, politics and languages—in fact, all the information required for making great strategical decisions, together with a description of the routes along which armies will probably pass. Operation and road maps with detailed reports on fortresses or strategical points are added, together with a topographical and statistical summary.

4. The Office for Railway, Steamship, Transport, Postal and Telegraphic matters, both at home and abroad, and the central direction for the transport of large bodies of troops either by rail or steamers.

5. The Office for Military History. It has produced some works of the highest value for military students.

6. The Office for Collecting Information on Foreign Armies. This division collects and classifies information concerning all foreign armies, and diffuses such information as widely as possible throughout the Austrian army. Maps of foreign countries are kept, with the territorial districts marked upon them, and statements giving the actual strength of the armies are attached to them and kept up to date. If information on any subject of more than ordinary interest be required, it is on hand and immediately available. The work of this division requires thirty-two officers, and the results of their labor are excellent.

The organization of the Italian General Staff is also analogous to that of the German. The peace establishment includes 140 officers, 85 of whom are attached to the Great General Staff. The Military Bureau, or Intelligence Branch proper, is divided into six sections:

1. *Statistical Section;* charged with collecting statistical information relative to all foreign armies.

2. *Historical Section;* charged with writing military history and collecting information relative to past military operations.

3. *Railway Section;* charged with studying the railway systems of Europe and their use in the movement and concentration of troops.

4. *Information Section;* charged with collecting information relative to foreign armies, embracing changes in arms, instruction, tactics, construction of fortifications, and other subjects of military value.

5. *Topographical Section;* charged with studying the topography and maps of all the theatres of war in which the army of Italy may be called to operate.

6. *Topographical Institute;* charged with the construction and completion of the map of Italy, and with the construction of maps of other countries.

The reorganization which has placed the army of France on a new footing since 1871, has been accompanied by a radical change in its General Staff. The total peace establishment at the Ministry and with the troops is fixed at 424 officers. The Intelligence Branch is under a chief of the General Staff, who is subordinate to the Minister of War. It is divided into five bureaus.

The *1st Bureau* deals with the general organization and mobilization of the army, plans the distribution of troops, and is charged with the correspondence of the staff.

The *2d Bureau* collects all information regarding foreign armies and navies. The great powers are studied separately, the small ones in groups. Special attention is paid to military institutions, organization, instruction, material, men and establishments. Naval affairs are treated in less detail, only so far as they affect the army. All this information must be arranged and classified so as to be at the immediate disposal of the Government or authorities interested. This bureau is charged also with distributing such information as may be desirable among the officers and men of the army. The preparation of military history is accorded it also.

The *3d Bureau* studies military operations and probable theatres of war, collects statistics, and prepares war maps.

The *4th Bureau* is charged with the study of provision and railway service, works out the details of communication and transport of troops by rail and water.

The *5th Bureau* is concerned with the care of maps, books and instruments, and with alterations to be made in the maps and statistics of the country.

The Sixth Division of the Quartermaster-General's Office at the Horse Guards in London is called the Intelligence Branch. Reports of military agents in foreign countries, and information of every kind concerning the territories and armies of foreign powers, are concentrated in this office. It is charged with the movements of troops by land and by sea, and with the preparation and issue of all the necessary plans and dispositions for attack or defence. In the topographical

subdivision is collected all necessary information concerning the geography, topography and resources of various theatres of war. This office has been for some time under the charge of Major-General Sir Archibald Alison, so conspicuous in the recent campaign in Egypt.

Lord Wolseley, writing on the Intelligence Department, says: "From the moment that war is declared until peace is made, it is of the utmost importance that we should know what the enemy is doing. A general who has the means of always learning the enemy's movements and intentions is certain to annihilate an adversary to whom his doings are unknown, all other things being equal. Napoleon said that a general operating in an inhabited country, who was ignorant of the enemy's doings and intentions, was ignorant of his profession; in writing on this subject to his brother in Spain he said that the single motive of procuring intelligence would be sufficient to authorize detachments of 3000 to 4000 men being made to seize local authorities, postoffices, etc. Until the troops are actually in the field, such information must be gleaned by our Intelligence Department in London"; and when in the field "the means of starting an Intelligence Department should, if possible, be taken from England or sent on before."

In February, 1882, complete plans of Alexandria and its surroundings were prepared, showing the class, location, command, range, and circle of fire of every gun mounted or probably to be mounted, all magazines, war stores, barracks, torpedo works, landing places, and railroads. These plans were reproduced and a copy furnished to the commanding officer of each vessel at the time that active operations were decided upon, and were of the greatest use in subsequent events. Five thousand war maps were supplied to the forces in Egypt; and such a store of information had been accumulated and kept posted to the latest moment that a correspondent of the *Whitehall Review* speaks of the Intelligence Office as "the eye and ear of the army up to the moment of actually taking the field, ever ready to furnish maps of the theatre of war, vocabularies for the officers, and statistics of population, provisions, and resources." In the field an Intelligence Corps was organized under General Sir Frederick Goldsmith, which collected all the information possible from spies, prisoners, deserters, the inhabitants, by intercepted letters, and by tapping the telegraph wires.

The Intelligence Branch has published during its short existence

several excellent works on the strength of foreign powers, and has compiled equally valuable military histories of English and of other wars.

It would seem that Egypt has received a lesson from her recent struggle with the English, for in the reorganization of her army an Intelligence Department has been established, with Sala Pasha as its chief.

The introduction of modern ideas into the army of Japan dates from 1867, when Napoleon III., at the solicitation of the Tycoon, sent out a military commission to instruct the Japanese troops in the tactics and the regulations of the different arms of service. The revolution of 1868 caused the recall of the commission, but no sooner had the government of the Mikado come in contact with the foreigners than, like that of the Tycoon, it perceived the value of military organization and training. On application of the Mikado, the Emperor of France appointed a second commission, which arrived in Japan in 1872. In 1876 the commission completed the organization of the Adjutant-General's department. For the transaction of business it is divided into seven sections, six of which constitute the Intelligence Branch. The *2d Section* collects military, statistical, and geographical information concerning Asia; the *3d*, concerning America and Europe. The *4th Section* is charged with the study and writing of military history. The *5th* and *6th* are the Geographical and Topographical Sections; while to the *7th* is assigned the printing, preservation and translation of records.

In the War Department of the United States there is no Intelligence Branch. General Upton, already quoted in this paper, recommends the abandonment of the system then—and even yet—pursued, and the establishment of a General and Great General Staff, under the General of the Army, and divided into three sections, the duties of two of them to be as follows: "The first of these sections should be charged with the collection of information and statistics relating to all foreign armies, but especially in reference to Mexico, Canada, and Cuba.

"The duties of the Second Section should be to write the military history of our wars, both Indian and civilized, thereby enabling our future officers to become familiar with the peculiarities of American fighting."

Again, he says, "The establishment of a Statistical Section would enable the General of the Army to have statements in readiness

showing the exact military resources of our neighbors, upon which calculations could be based as to the number of troops required for any given campaign. This system and this only will enable us in future wars to provide competent Chiefs of Staff, who have been so sadly wanting in all of our past wars."

Granting that previous knowledge and preparation are growing more and more necessary for success in war, let us see what kind of knowledge is required by any country—own own, for example.

First of all, our War Department ought to know our resources in men, arms, horses and money. It ought to know exactly what troops must be kept at home for the defence of the country, and such troops should be always assigned to the places they are to occupy. They should be definitely organized on paper as they must be in war, for such tedious questions should not be left to a time when all our energies should be free to mobilize and drill the immense armies that will be called on to defend the flag. Our staff should know the military features of our own country, and have thought over them so much in connection with the disposable force that there would be no difficulty in deciding upon the plan of the defence, no hurry or indecision at the last moment. Garrisons should be told off to their places and the great bulk of the remaining troops left to form a field army. Its strength, organization and means of supply should be arranged at leisure during peace, and the force available for a stroke against the enemy's territory should be ascertained and assigned accordingly. This force should be so correctly known and told off that nothing will remain to be done except the periodical substitution of the regiments as they are drilled and relieve each other in the ordinary course. Not only the force, but all its materiel and transport, should be definitely organized on paper. The railways or roads by which it will move to concentrate on the coast should be specified, and the exact number of trains or days' marches should be settled. Its telegraphic, postal, medical and hospital arrangements should be worked out in detail. In short, there should be an Intelligence Branch in our War Department, and that office should always be prepared to answer any questions, the most important of which would be, "How many troops are available for a movement on such a country, or how soon can they be organized and concentrated on the frontier or transported to the point of disembarkation to commence a campaign?" This is exactly what all the powers of Europe can do to-day. Arrived in the enemy's territory, the commander should

have all possible information concerning its resources, topography, statistics and people. He should have knowledge of the enemy's preparations, and there should be an Intelligence Corps to assist him in obtaining that information, if the principal office cannot supply it all, as would certainly be the case in any country. Another fact equally important, the commander should have his plan of campaign in readiness, so that his first blows may be struck at once. All these preparations can be so made in peace as to need only the last corrections according to circumstances when war is imminent. The army should be supplied with maps and carefully compiled handbooks of our country and of foreign territories, especially of those of our neighbors.

The naval authorities of Europe have also realized that there is no occult means by which neglect in peace can be atoned for in war. Most properly do they assert, as truer of navies than of armies, that if the required information be not ready it cannot be suddenly obtained. There is a general agreement that an intimate acquaintance should be had with the navies and naval institutions of foreign powers as well as with the home navy and its institutions; that a thorough military knowledge of foreign ports, coasts, rivers, and statistics should characterize their officers; that plans for the movement of troops by sea should be worked out for all probable contingencies and on a basis resulting from a study of home and foreign lines of communication; that naval history, drawn up according to official knowledge, is one of the greatest mines for information concerning the character of the seamen and the fighting powers and qualities of a navy; that all the information known to other governments should be published for the benefit of the home service; that war maps should be drawn up and issued to all vessels in commission; in short, that absolute preparation for naval war depends upon an absolute knowledge of the enemy's naval resources, both active and dormant.

This kind of preparation for war is considered quite as necessary as drilling the men or providing the equipment. It ensures the absence of delay and confusion at the beginning of the war, and enables a nation to make the best of its resources, whether they be large or small.

Germany has been also the first power to establish an Intelligence Branch in her Admiralty. The chief of the Admiralty at Berlin has the rank of an Admiral, is a Minister of State, and is entitled to represent his department in the Federal Council. He is also a member of the Naval Committee.

The Admiral's Staff consists of 1 Captain, 9 Commanders, and 7 Senior Lieutenants. His staff is described as "an establishment in the German Navy corresponding to the General Staff of the army, that is, it is a department on which devolves the duty, with respect to the organization and distribution of the navy, of executing and transmitting the orders of the Commander-in-Chief." The duties of the staff are performed by four divisions, known in the organization of the Admiralty as the *Military Sections*, by way of distinction from the technical and general sections. Of these four sections, two are charged with intelligence duties.

The First Section works out plans of preparation for war and extended operations, and superintends, through its study of foreign naval administrations, the mobilization of the fleet.

The Third Section collects and arranges information on home and foreign navies, as regards matériel, personnel, and resources; studies the coast defences of all foreign powers and works out systems of defence and attack; prepares war maps, and compiles and publishes naval law and history. It is charged, furthermore, with the collection of information concerning the statistics of foreign nations, especially as regards agriculture, coal, and supplies.

In France, the General Staff at the Ministry of Marine numbers thirteen principal officers. Under it is employed a large corps of subordinates and clerks. The Chief of the General Staff is a Rear Admiral. For purposes of work the organization of the Staff comprises three bureaus. The Chief of Staff is also chief of the 1st Bureau, which is charged with the correspondence and administrative duties both as regards the staff and the navy in general.

The 2d Bureau directs the movements of the fleet and military operations. It is divided into two sections. The intelligence duties of the first section consist in working out plans for naval operations in the colonies and on foreign coasts, and in elaborating systems for transporting both materiel and personnel; those of the second section, in the issue of war maps, and in the publication of scientific works, travels, and naval history.

The 3d Bureau is that of "Maritime Statistics and Study of Foreign Navies." It constitutes the intelligence department proper, and is under the charge of a Captain in the navy, an Aide-de-camp of the Minister, but subordinate to the Chief of Staff. This bureau is charged with the study of the maritime strength of the different powers and of the organization of their fleets; with the study of the progress made abroad

in the several branches of the naval and merchant services; with the examination of reports made by military and naval attachés, officers attached to boards or on a special mission, or commanding or travelling abroad; with documents and articles concerning the ministry of marine as found in the foreign journals, with the centralization of the telegraphic service, and with its cipher. A special branch of the general staff studies the system of coast defence both at home and abroad, and works out plans of attack and defence.

For several years it has been felt by the English government that an improved organization was required at the Admiralty for the collection and distribution of the information which came into the possession of that department on subjects bearing on foreign naval administration and organization. Previous to last year the only persons from whom intelligence of this description was derived were the captains of English men-of-war abroad, the military attachés at foreign courts, the Consular Agents, and two naval attachés, who were not resident in any particular country, but travelled to any part of the world where their services were at the moment most likely to be of avail. The reports and information thus derived came to hand in many cases after they had passed through the Foreign or War Office, and on being received at the Admiralty were referred to such of its branches as were most interested in the information contained. Thus intelligence regarding the naval gunnery of a foreign power was sent to the Director of Naval Ordnance, matters of supply were referred to the Director of Stores, while information bearing on the foreign methods of shipbuilding was passed to the Director of Naval Construction. Having been noted, they were passed to the Record Office, and were there available to such persons as were authorized to use them.

This system, though seemingly a good one, had many disadvantages. Coming through the Foreign or War Office, these unprofessional departments became the judges of what was important to the Admiralty; and frequently when important documents were transmitted to the Admiralty, it happened that, through a lack of responsibility attaching to any one, they did not reach the departments for which they were intended.

To remedy this evil and to supply the long-felt need of a department that should be *responsible* for the collection, transmission, and diffusion of home and foreign naval intelligence in its broadest meaning, an Intelligence Department was established at the Admiralty

during the summer of last year. This department is now the second division of the "Military Branch" of the Admiralty, and is under the direction of the First Naval Lord. At its head is a Captain in the Royal Navy.

It will not interfere in any way with the work hitherto done by the technical departments; these, as formerly, will be responsible for the fulness and correctness of the information on their particular subjects.

In the naval administration of foreign powers, the department for the collection of intelligence has occupied for a very long time a prominent place, and it is not a little surprising that in spite of the interest which Great Britain must always take in maritime matters, the Admiralty should have so long omitted to improve its organization for obtaining foreign intelligence. Its failure to do so is doubtless attributable to the superiority of England's naval system and fleet over those of other nations. Leading in maritime affairs, she has been the instructress rather than a pupil of her powerful neighbors. But now that she has a formidable rival exerting every strength to gain the naval supremacy of the sea, and sees every dockyard in Europe turning out powerful battleships, equal, and in some instances superior, to any in her own fleet, it has become necessary for her also to study thoroughly, through a Naval Intelligence Branch, the naval strength of other nations, but still more the vital question of *Imperial* defence—which means the protection of her colonies and lines of communication and her coal and food supply, involving also the safety and preservation of her enormous merchant marine. To this end the question of attack and defence, and especially of blockade, requires the thorough study of foreign ports and coasts—in general, of every subject that has any influence or bearing on naval affairs and operations.

There is an Intelligence Office in Norway and Sweden, Russia and Italy—all the powers of Europe have organized systems for keeping pace with what is going on abroad in naval affairs, and for collecting that information which will make them best prepared for war.

Reviewing the ground passed over, it is worthy of remark that in all these countries the intelligence duties are performed and directed by a zealous and efficient staff of officers devoted to their work, aided by all the available talent in the army and the navy. There is further a general agreement as to the facts that ought to be known and the manner of getting at the information.

No fact illustrates more forcibly the improvements and advances in modern warfare, or demonstrates more clearly the purely scientific principles upon which the conduct and tactics of such warfare are based, than the absolute necessity of this refined preparation in order to hope for success in operations against an enemy. Other things being equal, what is most required in war is knowledge of the enemy's position and strength. In *any* operation success will depend on knowledge down to the smallest detail of the work to be done. In the present condition of the world's military affairs an Intelligence Department will more than justify the expense of its organization and support, even if it serve no other purpose than to watch developments. But the collection, classification and diffusion of the information that falls within its scope do far more than this; they make a Government realize its military position and enable it to exercise intelligent forethought; and by that foreknowledge, if it be wise, it becomes forearmed. Even if it heed not the instruction it receives it will utilize its resources, however small, to greater advantage when the critical moment shall arrive.

If, then, such foreknowledge be required for the nations of Europe with their large armies and navies and strongly fortified coasts, how much more necessary is it for a country like ours, whose army is small and equipped with obsolete artillery; whose navy, so far as materiel is concerned, is antiquated and powerless, and whose coast defences scarcely deserve the name; how much more valuable will it be in an emergency to a government that has no special military or naval policy, not even that of self-defence, with which, in fact, the question of national defence has become since 1865 a Gordian knot that its "sword of representation" has failed to cut, and which must sooner or later discover its policy of self-reliant isolation to be a failure that can be remedied only by the substitution of guns and battle-ships.

That such a condition of affairs exists to-day is due to a great want of intelligence on the part of the public. There is a want of political intelligence and a very large want of intelligent acquaintance with our national position. The successes of the navy in the war of 1812, when England was fighting France, and in that of 1861, when operating against a territory that had no naval force to oppose it, have lulled our people into a sense of security and left them to fancy that there is sufficient time to prepare when war is actually upon us. Again, every boy in the United States has some ideas, however

vague, relative to soldiers, but millions of intelligent grown-up Americans to-day have no definite views at all as to a navy or the defence of the country by sea. It is no exaggeration to say that it would be difficult to find an American unconnected with the service who is ashamed to say that he knows nothing at all of our naval history and still less of the principles of naval operations and arrangements. We all realize that for some reason it seems the navy is popularly regarded in the United States merely "as an abstract quantity of national necessity," and that many people are puzzled to find why even this favor should be accorded it. A little leaven is thrown in occasionally when, as officers attached to a cruiser in one of our ports, we are told in post-prandial speeches that the scientific and educational world remembers us; but we inevitably feel that the recollection extends no further, and that with the end of speeches and wine is an end to thoughts of the navy. This cruiser goes to sea, encounters a gale of wind, and, having long intimated its fitness for Rotten Row, goes to the bottom. People east of the Alleghanies get angry and excited, and through ignorance of naval matters blame everybody but the right man. West of Cincinnati this public loss is scarcely appreciated. And during these intervals between mishaps which must occasionally happen, the popular mind is somewhat lethargic, if not wholly apathetic, of what in a foreign war would be our chief defence. Occasionally it is insisted that the navy must be powerful and must ever be ready to defend the "national honor," but how it shall do so few take the trouble to inquire.

Then, too, as a general rule, in legislation military questions are dealt with on broad principles. The amount and nature of force required to defend our territories against the Indians, the relation of artillery to infantry, or the erection of a fort, are questions that it is possible to discuss with a full house; but a discussion on naval matters tends to empty the house, and turns on the draught of a ship, the adoption of a certain torpedo, or the rank of some one who has seen little service; in other words, these debates show that our legislators are really "at sea" as regards general naval principles. It is popular to attribute all our deficiencies to "the advance of naval science," which probably means ordnance and armor. But the advancing science has done us no good, nor have we made the faintest effort to work out the great general principles that must guide our naval arrangements. Upon what does the elaboration of great general principles depend? Upon knowledge of the subject at hand. Let

us examine then the range of information that should be collected in an Intelligence Office.

Naval Intelligence comprehends within its scope a vast number of subjects widely different in their nature, but controlled by one great general consideration—the efficiency and adaptation of our naval means to the work to be done in war.

The principal duties that will fall to the naval service in a foreign war will be the protection of our ports and coast line, and, if possible, the attack of the enemy's commerce. It may have to resist the attempt of a blockade, and protect the great rivers whose valleys form the regions of our food supply. The extent of our seaboard may limit the operations of blockade, but the area of operations for the attack of commerce by us has practically no limits whatever. The two essential requisites will be therefore knowledge of our enemy's position on the one hand, and knowledge of our own on the other.

It can not be assumed that a sea-coast of such great extent as ours can be defended simply by the individual skill of our naval commanders. Should the present beginning result even in the formation of anything like a modern navy, our fleets must be separated by comparatively long sea intervals, and they can afford but little security to our enormous seaboard unless they act in combination and are subordinated to a general carefully prepared and preconcerted plan. The broad issues of our great national defence questions will therefore depend in their solutions upon a full knowledge of the resources of all those nations with whom we may become involved in war. To cite a point near at home and one that affects us intimately, both strategically and financially—Canada is now building a railway through Southern British Columbia to the Pacific. A competent English critic* has very cleverly said that this British Pacific Railway will give to England's naval position greater strategical security and strength than an extra half-dozen Inflexibles; and when the tide of emigration shall render the grain-producing land of British Columbia the source of England's food supply, the burning question of gold lace and precedence will have to lose much of its point and yield to that of our country's defence. To predict such a change in the region of England's grain trade is by no means so unreasonable as to have supposed in 1860 that within twenty years it would shift from the districts of the Euxine to the plains of our West.

* Captain Colomb, R. N.

On the other hand, the conditions that determine the defence of our ocean trade are almost the reverse. Notwithstanding the fact that more than one of our consuls has mentioned casually that the only masthead he ever saw with an American flag above it was the masthead of his own consulate, our people are still trusting to our great resources and national wealth to regain and eventually to surpass our former prestige on the sea. Even to-day we are in tonnage the second commercial nation of the world. If the navy be "the ally of commerce"—as it certainly is—we should remember in considering the protection of the latter that it is not fixed in value and direction, but varies with circumstances, that it obeys the eternal laws of supply and demand, and that the objects for which it is pursued being private and individual, it will defy the war policies of any nation and will exist as long as business is done. In its primary and real sphere, that of carrying the ocean trade of our country, and in its secondary or military capacity, that of supplying auxiliary cruisers and transports to the regular navy in time of war, the merchant marine after careful study leads to the enunciation of many facts that suggest and call for far-reaching systems of naval intelligence and principles of sea strategy; and it is needless to assert that the question of defence is still more imperative in its demands.

Having touched upon the two great purposes and duties of the navy—the protection of our coast and that of the merchant marine coupled with its adaptation to naval uses—let us pass to the more detailed subjects with which Naval Intelligence has to deal.

1. The naval administrations of all foreign powers, their organization, efficiency and arrangements.

2. The war policies and preparations of foreign nations as indicated by the vessels they build or purchase; and by their resources, both in actual service and in reserve.

3. The naval resources, both active and dormant, of all maritime nations, especially as regards character, distribution and capabilities. This involves the collection of information concerning the history, dimensions, machinery, turning powers, armor, coal capacity, speed, armament, type, efficiencies, deficiencies, vital parts and peculiarities of each and every war vessel afloat or building. With this information in store, a familiarity with the defensive requirements and war policy of a probable enemy, will enable us to estimate with great accuracy the exact number of battle-ships, rams, cruisers, gunboats, torpedo ships, torpedo boats, troop ships, coal and store vessels, that

she can bring against us on the outbreak of war and for a reasonable time thereafter. There has never been in the history of the world such wonderful activity and earnestness in naval matters as exist at present, and all this information should be known beforehand, for it will be in the *first* few weeks of war, rather than in the last, that the fate of any nation on the sea will be decided.

4. A knowledge of the dockyards and depots of any nation affords the key to the resources as regards the construction, refitment and maintenance of a fleet. An acquaintance with their approaches and defences is desirable and essential, for the destruction of any one of these stations means a loss to the enemy that cannot be repaired easily during a war, and a partial deprivation of the power of reinforcing himself on the water.

5. Ordnance and small-arm works, powder mills, and torpedo manufactories. As furnishing the first and most dangerous requisite in war, their position, resources and capacities should be known thoroughly. The size and nature of the guns, their reliability and methods of manufacture, the kind and quality of powder, and the revealed secrets of torpedoes, afford, even in peace, the means of comparison for the individual purposes of a government, and go far towards establishing the military status of a nation for war.

6. The principles and details of construction, armament, machinery and appliances as adopted in foreign services, and keeping pace with all inventions and improvements in the same.

7. Tactics and operations. The machinery, guns, armor, and types of vessels are changing continually and produce corresponding changes in the method of handling them in action. Ships are fought differently according as they are turretted or broadside vessels or a combination of these two types. Strictly speaking, there may be said to be no recognized system of naval tactics. In future every commanding officer will have to work out his arrangements and general plans beforehand, according to the character of his vessel or fleet. But the principles governing the fighting qualities of the several classes of vessels and the best methods of applying them in action may be arrived at simply from a knowledge of their construction and armament, coupled with their turning powers and speed. As an evidence of the interest taken in naval tactics alone, there is scarcely a service magazine published abroad that does not contain in each issue an article on the best methods of handling a fleet of armored ships in action.

The study of naval operations is coupled by its nature with that of tactics. It also involves other divisions of naval intelligence, such as defence, supplies, and fuel, which will be considered separately. These two subjects constitute an important element in the science of naval warfare.

8. The personnel, both active and reserve, of all war navies, as to numbers, organization, and discipline. Working or fighting a modern ship armed with breech-loading guns controlled by hydraulic or steam appliances, and involving delicacies of mechanism, the handling and firing of torpedoes—in fact, nearly all the requirements of naval service in the ships of to-day require a higher knowledge and more superior training than ever. The collection of information on foreign systems of naval education, both as regards officers and seamen, therefore holds an important place in the scope of naval intelligence. Reports by officers of their observations on the drills, evolutions and manner of performing duty in actual service by foreign ships, when collated in numbers, afford an excellent means of judging of the discipline and training of the personnel of a service. No commander without disciplined men can gain a victory, nor can the best trained seamen without an able commander.

9. The collection of intelligence concerning the Coast Guard and Naval Reserve. In England and France the duties of both these branches are performed by naval ships and men; but in our own and several other countries, the duties of corresponding branches fall wholly or in part to the civil departments of the government. In the United States, the vessels of the Revenue Marine, Light House Service, Fish Commission, and Coast Survey belong to the government, and as a rule are light, swift, and small. They can, however, be of great use to the navy in coast, bay, and river operations, for the carrying of despatches, transport of supplies and small bodies of men, and in a few instances might be of service in torpedo manœuvres. In this auxiliary sphere they should be studied, and plans for adapting them to naval use should be matured, preparatory for war. These remarks are equally true of foreign services; and while such vessels cannot engage in distant operations and may not affect us in case of war with a European power, yet we have neighbors, or nearly such, on this side of the Atlantic who might occasion us no little trouble by the skilful use of such aid in naval operations.

10. The topography of coast and river districts, including the most accurate and detailed information respecting railway, canal and tele-

graphic communications of war and mercantile ports. Especially should this subject be thoroughly mastered with reference to the ports of our country. It is reasonable to suppose that in the event of a war between the United States and a great naval power, the first attempt of our enemy will be aimed at the capture or destruction of our great cities on the seaboard, and in the present condition of our navy we could do but little towards opposing him in his design. This fact may be brought more vividly to mind by remembering that with the 100-ton guns, the Dandolo or Italia can lie south of Coney Island and destroy the business portions of New York, Brooklyn, or Jersey City, within a range of eleven miles. Sfax was bombarded by the French fleet with ease at a distance of 8000 yards. Blockade or its equivalent being then the policy of the hostile fleet, railways will afford facilities for moving fleets of efficient torpedo boats from one port to another more rapidly than by water, and it is reasonable to suppose that every effort would be made to raise the blockade through a cloud of torpedo boats. These latter can be built at any of the great cities in the interior and shipped to the seaboard by rail. The relative power of concentration possessed by the blockaders and the blockaded must exercise considerable influence on the strategical distribution of the blockading force. By reason of our decidedly isolated position, the power of concentration should be greatly in our favor. Railway and canal communications will also affect the question of fuel supplies, especially of the blockaded.

So far as oceans and seas are concerned it is probable that we are as well informed as any nation. But it is doubtful whether we know all that we ought respecting the military and naval value of the great rivers of the world, especially of those of Mexico, of Central America, and of the eastern countries of South America. The experiences and operations of our fleets during the civil war, on the Mississippi, James, and Potomac, must be familiar to all. Forts Henry and Donelson, Memphis, Vicksburg, Grand Gulf, New Orleans, Forts Philip and Jackson, all testify to the strategical value of rivers and the necessity of a thorough knowledge concerning the naval resources they afford the inhabitants of the country through which they pass. As their valleys are almost invariably the sources of food supply, it is needless to demonstrate further the practical importance attaching to them. Our late war was somewhat exceptional, as regards river operations, but similar experiences would be had in a conflict with any of the South American States already mentioned.

Telegraph lines afford the means of communicating information of all kinds, especially as regards the movements of the enemy. The location of telegraph offices, and the direction of the lines in their passage through a port, should be known so as to be readily cut or destroyed if deemed advisable.

11. All details concerning the exact position, nature of bottom and depth of water, in which submarine cables are laid, should be collected also and furnished to the commanders of ships and fleets, so that they may know where to cut or tap them, or prevent others from doing so.

12. Information concerning the direction of coal exports from all foreign countries and their colonies, also from such countries as export coal for steam sea traffic, the average supply and demand, and the ratio of increase at all home and foreign coaling stations, is most important and should be collected carefully. The commander of a vessel attacking an enemy's commerce, if he were doing his duty, would know at what points he could probably capture from one to perhaps a dozen of that enemy's coal ships per week; while his opponent, perhaps in search of him, might be on a main route miles away and not know where to find coal on the sea because such enemy had never had an opportunity of learning, if no system of naval intelligence had been organized in peace to put complete instructions, in war, on this and other subjects into his hands before he left port. It is a simple matter for a commander to know where to go. The interest of trade requires the publication of complete information for its own purposes. The instructions to commanders and the operation of cruisers can be calculated and prepared from information collected beforehand, and kept up to date from papers published in this and in other commercial countries, where secret agents can be sent if necessity dictate.

13. The laws that, under normal conditions, govern the distribution of our own and foreign sea commerce over the world, as regards time, place and value.

14. The special influence which any particular wars are likely to produce on the direction and value of our commerce passing over different ocean routes.

15. The careful and continuous observation of the development and resources of grain-producing lands, the periods of the harvest and the visible supplies available for export. These questions are of the greatest importance, as they have ever a controlling influence on the policy of a nation dependent on another for supplies. Apropos of the occasional assumption of a war with England, even the most

competent critics* of that country have acknowledged its practical impossibility for several years past. Great Britain is dependent on the United States for by far the greater proportion of her food, and a war with us means starvation and misery for the masses in England. But with the completion of the British Pacific Railway and with the greater development ensuing therefrom her grain can be grown under her own flag in thousands of acres now lying idle. She will then be independent of us, and an assumption of hostilities with her will then be worthy of every consideration and attention. The thought of a war with the mother country is naturally disagreeable to us for more reasons than one; it is suggested merely as an eventuality. Captain J. C. R. Colomb, Royal Navy, alluding to the protection of British commerce, says: "Every one knows that the harvests of the world are not simultaneous, and that when in one hemisphere they are reaping, in the other they are sowing. But there is another influence which determines the period of the year at which the crop reaches us, the sea distance it has to cover *before* it reaches us. For example, the wheat which comes to us from the North Pacific States of America is grown within a comparatively short distance from that which finds its way via the Northwest Atlantic, from the neighboring districts of the United States; but from the date of 'export' from those seaboards respectively until the date of its arrival here there is a difference of three and a half months. A grain vessel leaving Portland, Oregon, will, as regards time, be in war exposed to risk of capture for four and a half months, while the grain vessel simply crossing the North Atlantic will only be so exposed for one. North Pacific wheat will be accumulating in the South Pacific in the last quarter of the year, and more Australian wheat exposed to capture 'off the Horn' when the trees are budding in Hyde Park than at any other time. The dates and extent of maximum accumulations of our wheat, raw cotton and wool at various points in the ocean can be arrived at. . . . From a successful attack on our commerce in the Northwest Atlantic in the autumn we should suffer most as regards food. If that attack was delivered two or three months later, the hands in Manchester cotton mills would suffer the heaviest blow; if, however, in the spring of the year our commerce passing over the South Atlantic was interfered with, Yorkshire (wool) operatives would be the greatest victims. . . . . An import diagram of gold and silver would show a different distribution, but about the same amount coming as going; the South

* Captain Colomb, R. N., among them.

Pacific column would not be a blank, as on an average some five millions a year come from Australia." The most lucrative waters for gold, however, would be the North Seas, the Northeast and Northwest Atlantic, Indian Seas and North Pacific in all seasons of the year. The last-named ranks lowest in amount.

But equally important to ships is the knowledge of ports from which provisions can be obtained. Besides, where a country is deficient in its agricultural resources the necessity of absolute blockade is obvious.

16. Armies, as regards numbers, organization and equipment, especially of artillery. The value of naval co-operation with land forces was thoroughly demonstrated in the Civil War, and more recently in the Egyptian Campaign of 1882. Commander N. H. Farquhar, United States Navy, says: "While the navy is not expected to engage an army, still it can create a diversion by attacking at some remote point, rendering necessary a division of the enemy's army. Had the French navy done this during their recent war with Germany the result might have been different. Its inactivity, it is believed, enabled the Germans to concentrate their forces and thus overwhelm their enemy."

17. The necessity for collecting and rapidly disseminating information concerning the movements of an enemy's war vessels is so obvious as to need no explanation. If any people should appreciate this fact it should be those of our own country. Between 1860 and 1864 the American tonnage was reduced by some 2,000,000 tons through the terror inspired by an uncaught Alabama. Nor was she caught—if her commander is to be believed—until driven into Cherbourg through need of repairs. The history of that famous vessel's career shows on every page the abundance of naval intelligence possessed by her commander—and chiefly through his own energies—both as regards United States war vessels and lines of commerce, while her success establishes the total absence of it in Federal arrangements.* The wrecks of thirty American ships were seen on the shores of Behring's Straits, a proof of the information possessed by the commander of the Shenandoah and of the ignorance of United States authorities concerning that vessel's movements and depredations.

* The projected cruise of the Vanderbilt possibly forms *one*—and the *only*—exception to this statement.—*Author.*

18. The details of construction and speed of every merchant steamer in the world that can be adapted as a war cruiser of attack. Her employment and ownership, coal capacity, route and details of machinery should be known, no matter what her nationality may be. The transfer of such vessels from one flag to another is an easy matter before hostilities begin. Besides, in war enormous national interests are at stake, and though such an undertaking may seem impracticable, it should be remembered that there are not so very many steamers under foreign flags suitable for conversion into efficient war cruisers. Nearly three hundred merchant steamers have reported to the Admiralty their compliance with the regulations for adaptation to war purposes, and to-day guns, magazines and stores are being sent from England to the colonial depots, ready for such vessels in the event of war. Most thoroughly should this subject be studied with reference to our own merchant marine. The number of horses and of men that each can carry should be calculated in event of their use as transports. The character of the ships for such work should be decided while there is plenty of time to think the subject out quietly. Even the boats required for embarking and disembarking should not be forgotten nor the means of supply for the first few days.

19. Intimately connected with the foregoing division is that of communications or steamer lines. Strategically considered, the success of all naval operations depends upon the disposition of force in such a manner as will best secure the base and ensure safety and freedom of communication. The greatest danger to which communications are exposed is that which threatens the greatest number at one and the same time.

If our aim be the attack of an enemy's commerce, we should remember that communications or steamer lines can only be secured by a firm grasp of the points which command them. To this end the trade lines of every nation should be carefully worked out, their points of junction or areas of concentration properly defined by latitudes and longitudes, the directions of the routes closely studied both as regards sail and steam vessels, and the relative amount of such commerce passing over these lines during each quarter of the year should be calculated or arranged. Accumulations of commerce are not simultaneous, and the duty of an office of Naval Intelligence would be to know how, when and where the major and minor accumulations are taking place. The areas of crossing, or more properly speaking the areas of concentration, would naturally be the places to

find the greatest number of the enemy's vessels in any particular season of the year. And the greater the extent of the lines, the greater is the number of points at which they can be attacked. In order to cut a line of communication, the first thing to do is to seize the point that commands it; and if defending one of our own lines, the point that commands it should be the last to surrender. But to bring fact to the aid of theory, a quotation from Captain Semmes will not be out of place. On board the Sumter in the West Indies, he remarks: "The enemy has done us the honor to send in pursuit of us the Powhatan, the Niagara, the Iroquois, the Keystone and the San Jacinto." But none of these vessels ever caught her. Again, "The Mona passage being the regular track of United States commerce, it was looked upon as almost a certainty that at least one cruiser would be stationed for its protection." This presumption was a delusion, however. Several months subsequent to this he asks, "Where can all the enemy's cruisers be that the important passages we have lately passed through are all left unguarded?" He sarcastically answers, "They are off, I suppose, in chase of the Alabama." At another time he says: "The sea has its highways and byways as well as the land. If Mr. Welles had stationed a heavier and faster ship—and he had a number of both heavier and faster ships—at the crossing of the thirtieth parallel, another at or near the equator, a little to the eastward of Fernando de Noronha, and a third off Bahia, he must have driven me off or greatly crippled me in my movements. A few ships in the other chief highways and his commerce would have been pretty well protected. But the old gentleman does not seem to have thought of stationing a ship anywhere."

All the naval force of the United States was powerless to arrest a single ship in her progress, and why? Simply because that fleet was applied without reference to general principles that guide the distribution of force for the protection of communications.

20. Ports—their defence and attack. The strategical position of ports should be studied with reference to the location of batteries, natural advantages, and probable location of temporary defences. The calibres and ranges of the guns in the faces of each fort should be known, as well as the position of firing stations for torpedoes and the facilities for defence by torpedo boats. The probable garrison of every important port, its communications, facilities for supplies, commercial value, and resources should be collated and furnished to commanders of naval vessels. The best position for an attacking

force, facilities for landing, points to be bombarded or spared, can all be worked out in time of peace, leaving the plans to be modified according to the circumstances of defence in actual war. War maps should be issued, showing the location of forts and other defences, with their fields of fire marked out by plotted ranges. A fleet attacking a port will then know how to approach it so as to avoid the greatest field of fire and encounter only the least. Statements appended or printed on the map and kept corrected to date would show all the data of materiel employed in defence. All other information should be published in manuals and furnished to ships of war. By this means all admirals and commanders of vessels at home and abroad would know exactly every gun, ship, or torpedo boat on the coasts embraced in the limits of their respective stations. Such information would be invaluable in case of war, and without it no reasonable hope can be entertained for success. Too much attention cannot be directed to our own ports. The whole system of our defence should be organized in time of peace; and when once the plans for defending a place have been worked out, our ships should go and drill and see how it can be done with all the disposable force on hand, and how batteries, torpedoes, and gunboats or armored vessels can be made to work in concert. We ought to have a plan and a system of defence, now and always, so that when war comes we may not have to improvise one.

21. The compilation and publication of histories of all naval wars, whether at home or abroad. It is by the study of such history that we learn the character and qualities of a nation's personnel as well as their fighting powers and the efficiency of its materiel.

Such are the principal subjects that fall within the province of Naval Intelligence. Collectively they form the science of naval warfare. Their study, arrangement, and diffusion constitute the work of the office in which they are collected. How necessary they are, especially to us, must be evident to all acquainted with the naval status and history of our country. If not, an examination of the records of the Civil War will relieve the mind of all doubt. In this connection it is worthy of note that a board composed of two naval officers, a major in the army, and a civilian were appointed *at the outbreak of the war* to examine and report *on the coast of the enemy, the approaches to its ports and its defences.* Battles were fought, within half a day's journey of the National Capitol, on territory whose topography was entirely unknown beforehand to the commanders of

the United States Army. It is also a significant fact that Mr. T. A. Scott, a civilian and director of the Pennsylvania Railroad Company, was the first to ascertain that Lee's army was concentrating on Gettysburg instead of Chambersburg, and communicated such information to one of the officers of the Union Army.* Scores of examples could be cited to show a surprising lack of information concerning the enemy's movements, resources, and country, on the part of both army and navy throughout that long and interesting war. But they are recorded on the pages of histories that have been written by participants in the strife, and there they can be found. How much our government would have gained by absolute preparation in this respect must ever remain a matter of speculation. But it is safe to say that in money her savings would be counted, not by hundreds or thousands, but rather by millions of dollars, in lives by thousands, and in length of war by one-third or one-half the years rather than by days or months.

As to the administrative sphere of an Intelligence Department, its very essence is that it is in no sense executive. It robs no one of power; it encroaches upon no one's authority; it must ask for information from all and be ready to give information in return. It is a worker for all departments, all bureaus, and all officers of the Government, whether civil or military. The pursuit of information has no tendency to bring about war; for an office of Naval Intelligence has no business except to be ever on the watch to gain, to arrange and to distribute information. To perform its work honestly, to be a real serviceable institution free from all suspicion of pretence, it must have workers, men devoted to their labor, and plenty of them; in order to be felt it must have considerable freedom in the use of the printing press. While no confidence should ever be betrayed, there can be no objection to publishing in English what is published in all other languages. To lock up from our officers information that is freely distributed to foreign navies is to put our own service at a dangerous disadvantage. And it is reasonable and just to suppose that much good and no harm can arise from direct personal and official communication between an Intelligence Office and the State, Treasury, and War Departments, all of which must be consulted in time of hostilities.

The most important information must come from abroad. Officers in a foreign country can ascertain much from actual observation con-

* Comte de Paris, "History of the Civil War in America."

cerning the naval and military institutions and fighting powers of the services with which they come in contact.

An officer on special duty and officially accredited in a foreign country must preserve great tact and discretion, and any attempt to procure information secretly and on forbidden ground would be unjustifiable and exceedingly compromising on his part.

Again, the courtesy usually shown a foreign officer by the authorities of another country compels him to restrict himself in his reports to what has been voluntarily placed within his reach. Should the latter, however, not meet the ends desired, freedom of action on his part can be resorted to by having no further reference to, and taking no further advantage of, the support or assistance of the authorities of the country in which he may be gathering information.

The inspection of a foreign ship or fortress is necessarily of a superficial nature; but by learning their history beforehand, and, if a fort, by carefully studying its map, the existing information can be brought up to date and any changes that have taken place noted. In ships the armor, guns, angle of fire, ram, vulnerable points, steering gear and protection of vital parts are conspicuous and essential points. In fortresses attention should be paid to the casemates, communications, water and inundations, works constructed in advance, the armament, stores and arsenals.

Every intelligence officer should establish some system by which all information that he may glean from individual officers, or any other source, can be at once noted, and nothing, however seemingly unimportant, omitted. Although trivial points establish but little, yet when collated in numbers and compared with the information received from other sources, each small piece may become an important link in the chain of information.

If there has ever been a time when our country should prepare itself for war it is now. There are many of our people who decry all steps in this direction, among them some who carry the weight of experience if not of authority. Only a few weeks ago, when the country was oppressed with valedictory orations and school-girl essays, an ex-officer, who attained some distinction in the army as the commander of a brigade, alluded to this subject, and said to a graduating class: "Let our title be the Unarmed Nation." In substance he cited the famous Praetorian Guards as usual, and drew a picture of America without offensive or defensive weapons, yet crushing with her weight of peace and trade the war systems of the world,

and establishing instead the ease, luxury and quiet of the Millennium. The United States becomes a grand Western Empire dazzling in its wealth and magnificence, with freeborn and unarmed sentinels who pace the shores and highways of the amiable realm, and cry in the English tongue at every hour of the night, "All is well in the Empire of Peace." It was a pretty picture, full of pleasant dreams, and suggesting the enthusiasm of a disciple of Ariosto. But he forgot the true spirit of liberty, and those who remember the wars of the past twenty-five years, and are more skeptical of America's power and the good nature of the human race, will prefer the more practical story of Ariosto himself about "a fairy who, by some mysterious law of her nature, was condemned to appear at certain seasons in the form of a foul and poisonous snake. Those who injured her during the period of her disguise were forever excluded from participation in the blessings which she bestowed. But to those who, in spite of her loathsome aspect, pitied and *protected* her, she afterwards revealed herself in the beautiful and celestial form that was natural to her, accompanied their steps, granted all their wishes, filled their houses with wealth, made them happy in love and *victorious in war*. Such a spirit is Liberty. At times she takes the form of a hateful reptile. She grovels, she hisses, she stings. But woe to those who in disgust shall venture to crush her! And happy are those who, having dared to receive her in her degraded and frightful shape, shall at length be rewarded by her in the time of her beauty and glory."

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LIEUTENANT R. WAINWRIGHT, U. S. N., in the Chair.

THE EVOLUTION OF COURTS-MARTIAL.

By LIEUTENANT NATHAN SARGENT, U. S. N.

The development of courts-martial from their primordial form in the courts of chivalry to the model of to-day, is a subject somewhat difficult to investigate, so many customs and formalities having been the result of usage arising from necessities that have left no trace on the records or legislation of their time.

In many cases, the origin of these customs can only be surmised from occasional disclosures which reward a careful examination of the meagre sources of information on the subject, or from the narration of certain events, cited as analogous to others of an earlier date. The greater part of relevant legislation has been comparatively modern, and so occasional that it sometimes appears to have been enacted for the purpose of sanctioning practices and modes of procedure that had arisen without its authority. By it, however, we can satisfactorily follow the progressive growth of courts-martial to the form with which we are now familiar, and can especially note the changes that have taken place during the last three centuries, since the time when the power of the court of chivalry was, by various statutes, curtailed, abridged, and finally annulled, and the authority of the court-martial was recognized, legalized and established. In this article it is purposed to follow, so far as possible, the history of courts-martial as relating to the naval service, only referring to the legislation concerning army courts, where it becomes necessary in order to maintain the continuity of the subject.

In the middle ages, the management of horses and the training of them to military usage, was conspicuous, and those who distinguished themselves in the cavalry took a natural precedence over other warriors. Tacitus describes the horsemen as the flower of the German army,* who, as a mark of their superiority, were allowed to carry arms at all times, a right that was given them with much ceremony, as the first honor of their youth. When, on the fall of the Roman Empire, the people of Northern Europe began to form their extensive realms, their leaders and valuable soldiers whose services were to be requited, received lands, in lieu of pay, from the chiefs they had served; their titles were soon made hereditary, and thus began the feudal system. Another cause of the substitution of feudalism for the freehold system which first prevailed, was the change in armament and tactics. Heavily armed cavalry was the most powerful factor in the combats of the time, and represented an expense which could be borne only by the wealthy nobles. The cavalry, therefore, was held in the highest estimation, and soon gave its name to the institution established for the mutual benefit and protection of mankind.†

It cannot be proven at what time and in what country chivalry was first established,‡ but it was one of those blessings that seemed to have been vouchsafed the world at a period when nothing else would have taken its place.§ Of course, in time it deteriorated, and becoming corrupt, had its abuses; but when it flourished, the good it accomplished at a time when only violence might have reigned; the principles it upheld in an age when treachery and corruption might have been expected; the virtues it not only professed but practiced, in an unenlightened era when debauchery and dissipation might have been looked for; the grace of manner it inculcated when boorishness and coarseness might have prevailed; the tender regard for and protection of women and the helpless, when brute force might have been the only consideration; and finally, the contributions to literature in the

* Tacitus. De Moribus Germanorum, C. XXXII. Tencteri* super solitum bellorum decus equestris disciplinae arte praecellunt; nec major apud Cattos* peditum laus quam Tencteris Equitum. Sic instituere majores, posteri imitantur. Hi lusus infantium, haec juvenum aemulatio; perverant senes. Inter familiam et penates et jura successionum equi traduntur; excepit filius non ut cetera, maximus natu, sed pro ut ferox bello et melior.

† Chivalry, chevalerie, Fr. knighthood. Cheval, a horse, from caballarius, L.

‡ Hist. of Chivalry. Kottenkamp.

§ It is supposed to have been instituted in the time of Hugh Capet.

* Names of German tribes.

romances of the period, the songs of the Troubadours, and the epics illustrative of its customs and deeds of valor—all these were of incalculable benefit to the world and the age in which they flourished. With it was laid the foundation of those high principles of honor and uprightness that distinguish those who have received a military education and have become imbued with the traditions of the service to which they belong. The customs of the members of the different orders of chivalry show a singular contrast of religion and gallantry, of magnificence and simplicity, of bravery and submission; a mixture of skill and force, of patience and courage. They were conspicuous for enterprise and devotion to duty, ready for any undertaking, however hazardous, and were the natural leaders of their dependants, and of the turbulent masses that composed the armies of their day. The education received by them peculiarly fitted them for the position they were afterwards to hold. It commenced at the early age of seven, when the boy was taken from his mother's care and given to that of men. Everything was done to make him strong, robust, and perfect in all martial exercises, and to eradicate all effeminateness in his nature. The presence of his father even was considered objectionable, lest paternal affection should shield him from some of the hardships he should learn to endure. He was, therefore, taken to the court of some neighboring baron or prince, whose establishments were always open as schools where the young gentry could receive their first lessons in the profession they were to adopt.* To thus accept the hospitality of some illustrious chevalier was considered in no wise servile or degrading; it was simply giving favor for favor with the expectation of returning, in the future, the services of a son, to the one who had occupied the place of a father. The independence enjoyed in those days by the nobles rendered them so powerful that it is not to be wondered at if they imitated the royal dignity, not only in splendor, but in the ceremony and appointments of their petty courts, where could be seen such officers, in name at least, as were met with at the court of their sovereign, the difference being, that where the king committed such positions to the highest nobility, the nobles distributed them to their friends and relatives. With them, therefore, was always to be found a number of youths, occupying the different subordinate positions which it was requisite to pass through, before becoming, first the squire, and ultimately the knight. These youths were exercised continually in every way that could strengthen and inure

* Memoires sur l'ancienne Chevalerie. Sainte Palaye, Paris, 1781.

the body to all hardships, and give them the skill and agility necessary to the tourney and warfare of the day; they were perfected in management of the horse, and taught everything relating to the care of that animal; the manners of the court and the knowledge of the time were imparted to them, and the young aspirant to the honors of chivalry not only worked assiduously to perfect himself for duty in the field, but strove to appear with all the advantage that can be given by grace of manner, politeness, choice of language, modesty and wisdom. In his capacity of attendant he acquired the art of speaking by being long silent, and by listening to the romances and flowery conversations of that day. Much of the learning of the time was confined to the knights, and was disseminated by them and by the wandering minstrels and pilgrims who sought the hospitality of their roofs.*

The mind of the youth expanded, therefore, with his body, and he soon combined the strength necessary for the most arduous undertakings, with address, intelligence and knowledge to aid him in their accomplishment. Before being knighted he had to go through numerous ceremonials and to take upon him the vows of chivalry, among which the one of the greatest prominence was that insisting upon the necessity of explicit and inviolable truth in speech and action, and expressing the greatest detestation of falsehood and treachery. The ceremonies ended with the accolade and form of investiture, concluding with the words "soyez preux, hardi et loyal."†

The birth and position of a chevalier made him a born judge—first, of his peers, and, secondly, of his dependants holding his feoffs,‡ and by the accepted ideas and customs of chivalry he would have been as greatly dishonored by any sentence contrary to law or justice, as he would have been on the field of battle, by any action, unrecognized by

* Froissart in speaking of the court of the Comte de Foix says: "On veoit en la salle, en la chambre, en la cour, chevaliers et ecuyers d'honneur, aller et marcher, et les oyoit-on parler d'armes et d'amour; tout honneur etoit là dedans trouvé; toute nouvelle ne de quelque royaume que ce fust, là dedans on y apprenoit; car de tout pays pour la vaillance du Seigneur elles y venoient."

† The navy also had its chevaliers. Eustace Deschamps, a poet of the time of Charles VI, wrote:

"Bons sont les chevaliers de terre,
Bons sont les chevaliers de mer."

Froissart also speaks of the English knighting some members of the fleet in 1333.

‡ Memoires sur l'ancienne Chevalerie. Ste. Palaye.

the laws of combat. Being in this manner frequently called upon to act in a judicial capacity, and, therefore, conversant with the administration of justice, it was natural that he should form a part of some tribunal to which could be referred all disputes and differences, and so prevent the lawless violence which might have obtained.

The court of chivalry was, therefore, established to hear complaints and to decide all quarrels; or, as the alternative, to appoint a time, place, and lists for a meeting to decide the disputed point by single combat.*

The court was held before a presiding officer called, first the Mareschall or Marshal, and later the Earl Marshal, from which the derivation of the modern name Cour Mareschall, or Court Martial, can readily be traced.†

The courts of chivalry were thus originated for the benefit only of the nobles and members of the different orders of knighthood, but their jurisdiction was soon extended to military, and occasionally even to civil, cases. In Normandy the power and authority of the Earl Marshal was great, and it was natural that the office and the court should have been instituted in England by the Duke of Normandy when he had gained his appellation of William the Conqueror. He introduced the order of single combat, and by it the protection of the court of chivalry was afforded to those who were entitled to enter the tourney. Later he established the Aula Regis, or Supreme Court, in which was blended the jurisdiction of the court of chivalry‡ or marshal's court, at which the Constable and Earl Marshal presided (secundum legem armorum) in all matters of honor and arms.§

Under Edward I the Aula Regis became obnoxious to the people and was subdivided into different courts,|| the court of chivalry having

* In a combat for life, the cartel of challenge was preferred to the Earl Marshal, with a petition that he would obtain the license of the sovereign. The victor was adjudged innocent. If, however, the challenger did not vanquish the defender before sunset of the day appointed, he was considered vanquished, and could not after challenge any one. Robson's Hist. of Heraldry.

† Mareschall, from Saxon mare, a horse, and schall, governor.

‡ Called also the Curia Militaris.

§ Blackstone's Com., B. III, c. iv.

The Lord High Constable and Earl Marshal, being the principal officers of the military household of the king, had particular charge of any troops that were employed, and were responsible for their discipline.

|| One of the objections to the Aula Regis was the inconvenience attending its moving from place to place with the king.

a separate jurisdiction, and being presided over by the Constable and Earl Marshal. It was then considered a military court or court of honor when held before the Earl Marshal only, and a criminal court when held before the Lord High Constable jointly with the Earl Marshal.* In the time of Richard II (1389) the Commons preferred a complaint to the effect that the court of the Constable and Marshal encroached on the actions, etc., pertaining to the common law. An ordinance was accordingly passed defining the powers of this court as relating to military matters in general without the realm, and also such matters of the same description within the kingdom as were not taken cognizance of by the common law.†

Blackstone tells us that the court had then jurisdiction over pleas of life and member arising in matters of arms and deeds of war, as well out of the realm as within it; but the criminal as well as civil part of its authority is fallen into entire disuse, there having been no permanent High Constable of England (but only *pro hac vice*, at coronations and the like) since the attainder and execution of Stafford, Duke of Buckingham, in the thirteenth year of Henry VIII, the last Lord High Constable before which the court had to be held.‡ From the sentences of this court an appeal lay immediately to the king. It grew out of use on account of the feebleness of its jurisdiction and want of power to enforce its judgments, as it could neither fine nor imprison.§

In the time of Richard II there was also an Admiral's Court, which partly was charged with disciplinary measures for government and merchant vessels, and also had the jurisdiction of the present civil

* Blackstone's Com., B. IV, c. xix.

† 13 Richard II, c. 2. Al Conestable appartient davoir conissance des contractz tochantz fait darmes et de guerre hors du Roialme et auxint (aussi) des choses qe touchent armes ou guerre deinz (dans) le Roialme queux ne poent (peuvent) estre terminez ne discus par la commune ley, ove (avec) autres usages et custumes a ycelles materes appurtenantz, queux autres conestables devant ore ont duement et resonablement usez en lour (leur) temps.

During this same reign the Constable and Marshal drew up a code of rules prescribing penalties for military offences. Adye, Treatise on Courts Martial, London, 1797.

‡ Blackstone's Com., B. IV, c. xix.

§ Blackstone's Com., B. III, c. v.

At the restoration of Charles II an attempt was made to re-establish it. The necessity for such a court was, however, no longer felt, and the attempt was ineffectual.

court of Admiralty.* In 1391 a complaint was made that the Admiral's court took too much authority on itself, and an act was accordingly passed defining its jurisdiction. By it we see that it was supposed to try cases of murder and mayhem on the high seas and on board ships in rivers near the sea; also to charter or seize vessels for military and naval expeditions,† and during such voyages to have jurisdiction over them.‡ In cases of the desertion of sailors enlisted and receiving pay in the king's service, their cases were examined into by the Admiral and his lieutenant, and the offender was fined and imprisoned for one year.§

At that time there was no regularly established navy—that is to say, there was no such military body, and the fleets used for the transportation of troops consisted principally of vessels seized for that purpose, and of men enlisted for the campaign only.

By subsequent legislation the Admiral's court gradually changed its character and assumed that of the present Court of Admiralty.

From the time when the court of chivalry was abridged of its criminal jurisdiction by the suppression of the post of Constable, to the Revolution of 1642, there was no regular court for the enforcement of martial or military law; and although desertion was made felony,‖ and other military crimes were made punishable by fines, imprisonment and loss of service, yet the civil justices were charged with hearing and determining these offences.¶ During the reigns of Mary, Elizabeth, and notably Charles I, several proclamations were issued** declaring certain offences punishable by martial law; but this was an

* 13 Richard II, c. v. . . . Accordez et assentu qe les Admiralx et lour deputeez ne soi mellent defore enavant de null chose fait deinz le Roialme, mes soulement de choses fait sur le meer solone ceo qud este duement use le temps du noble Roy Edward, aiel nostre Seignur le Roy qor est.

† The first English man-of-war on record as a vessel exclusively used for that purpose was the Great Harry, built by Henry VII about 1490. She cost £14,000 and was burned in 1553. Twenty years later was built the famous Henri Grace de Dieu.

‡ 15 Richard II, c. 3. § 2 Richard II, c. 4. ‖ 2 Edward VI, c. 2.

¶ 7 Henry VIII, 18 Henry VI, for soldiers, and 5 Elizabeth for mariners and gunners.

** In the reign of Mary there was one to the effect that whoever was possessed of heretical books should be punished by martial law. Elizabeth, upon some disturbances by the London apprentices, noted in that time for their turbulence, made the Lord Mayor of London provost marshal, with power to proceed against them by martial law. Adye's Treatise, London, 1797.

exercise of unauthorized power, and we can find no record of the manner of proceeding other than it was prescribed that the courts-martial should sit as those that were used in the armies in time of war.

Charles I availed himself of this illegal method of coercing the people into granting him supplies; but finding even this measure ineffectual, he was obliged to have recourse to Parliament, which, before granting him any money, insisted on his assenting to the bill called the Petition of Rights, one clause of which was to the effect that the commissions for proceeding by martial law should be dissolved and annulled, and no such commissions should be issued for the future. He pledged himself never again to imprison any one except in due course of law, and never again to subject his people to the jurisdiction of courts-martial.*

Before the King and Parliament came to an open rupture it was proposed that he should disband ten regiments, and the Earl of Holland, then General of the army, declared that the troops could not be safely disbanded, unless power was given them to punish such as should refuse to be discharged. The Commons preferred, however, rather than commit themselves by any legislation, to desire the General to execute martial law himself on such as were refractory.† With the Parliamentary Army, an ordinance appointing commissioners for executing martial law passed both houses, by which it was enacted that the Earl of Essex, General of the forces, together with fifty-six others (among whom were several peers, members of the Lower House, and field officers of the army, or any twelve or more of them, three of whom were to be members of either house holding commissions or command), should be commissioners, and have full power and authority to hear and determine all such causes as belonged to military cognizance, and to proceed to the trial of all offenders against the articles mentioned in the ordinance. These articles were the model for the subsequent Mutiny Act. By them was regulated punishment for different offences, and the court was empowered to sit, and to appoint a judge advocate, a provost marshal, and all other needful officers. By this legislation, the first directly authorizing courts-martial, we see that they had, before this, been in use, in time of war, and that the custom of having a judge advocate and provost marshal had already been adopted, although there had been no legislation to sanction it, or any of the forms of procedure.

The Long Parliament also (1645) passed an ordinance concerning

* Macaulay's Hist., c. I, p. 64. † Parliamentary Hist., v. 9, p. 432.

martial law for the governance of the navy.* Under this ordinance Blake and Monk issued instructions for the holding of general and ship courts-martial, with written records;† the one for captains and commanders, the other for subordinate officers and men. Of the latter the gunner and boatswain were members, but the Admiral reserved a control over more serious sentences.‡

Soon after his restoration Charles II attempted to form something of a standing army, by recruiting some household troops and five other regiments, one of which, called the Admiral's regiment, was for service on board ship. But the discipline was lax, and could not be otherwise, as Parliament and the English people were greatly opposed to any troops being maintained, and would enact no law for their governance. "The common law of England knew nothing of courts-martial, and made no distinction in time of peace between a soldier and any other subject. * * * A soldier, therefore, by knocking down his colonel incurred only the ordinary penalties of assault and battery; and by refusing to obey orders, by sleeping on guard, or by deserting his colors, incurred no legal penalty at all. Military punishments were doubtless inflicted during the reign of Charles II, but they were inflicted very sparingly and in such a manner as not to attract public notice."§

With their remembrance of the exactions of Charles I and the tyranny of Cromwell's troopers, the English people felt a natural repugnance to a standing army, and not until the reign of William and Mary was there passed any legislation either authorizing or recognizing it.

It was not so, however, with the navy. The navy had often proved the salvation of the country in the numerous contests with the Spaniards, the French, and the Dutch; its guns had been turned against foreign foes only; parliament had never been overawed by its power, and the English people looked on their wooden walls as a sure protection against any invader, and on its personnel as a reliable

* The only record of any penalties for offences before this action of Parliament was that of some few punishments for sailors in general, as found in the curious old Black Book of the Admiralty.

† W. C. Smith, LL. B., in Encyc. Brit.

‡ The legislation of the time of the Commonwealth is difficult to trace, as all publications of the English statutes ignore anything that was enacted during the king's absence from the country. By a legal fiction the king did not cease to reign.

§ Macaulay's Hist., c. III.

force for any emergency, and not as one that might be perniciously used against them. Under Charles, however, the navy was allowed to deteriorate, its funds were misappropriated and its discipline relaxed. Parliament realizing its condition, money in abundance was voted and laws passed to improve its discipline, but the money was misused or squandered, and the laws not carried out. The picture drawn by Pepys and Macaulay, of the state of the English navy during this reign, reminds us in some respects of our own misfortunes. Its ships were rotten; some few new ones had been built with the money appropriated by Parliament, but had been made of such poor timber that they were unfit to go to sea; officers and sailors were unpaid; supplies were worthless, and provisions uneatable. The discipline corresponded with the matériel. Captains who had hardly attained their majority, some of whom had never been to sea, were given the command of the finest ships, and, by reason of their influence at court, felt themselves independent of their Admiral, and disregarded his orders; in turn, for their ignorance and incompetency, they were despised by their subordinates, who often, though thorough seamen, were coarse and unrefined in their manners and habits. "It does not appear that there was in the service of any of the Stuarts a single naval officer such as, according to the notions of our times, a naval officer ought to be; that is to say, a man versed in the theory and practice of his calling, and steeled against all the dangers of battle and tempest, yet of cultivated mind and polished manners. There were gentlemen, and there were seamen, in the navy of Charles the Second; but the seamen were not gentlemen; and the gentlemen were not seamen."* One of the attempts of Parliament to improve the condition of the service was the framing of its first code of laws in the statute known as the 13 Charles II, c. 9, by which crimes and offences were specified and were directed to be inquired into and tried by courts-martial holden for that purpose.† The Lord High Admiral had authority to grant commissions to Vice-Admirals and Commanders in Chief of Squadrons, to call and assemble courts-martial consisting of Commanders and Captains not less than five in number in all capital cases. Provision was also made for a Judge Advocate, who was empowered to administer oaths, examine witnesses, etc. These articles were in many respects the same as the ones by which we are

* Macaulay, Hist. of England, c. III, pp. 222–228.

†"An Act for Establishing Articles and Orders for the regulating and better government of His Majesties Navies, Ships of Warr, and Forces by Sea."

now governed. Of course in time new matter has been added and some old regulations have been omitted, but in the main the "Articles for the Government of the Navy" are a reproduction of those issued under Charles the Second in 1661.* A singular feature of this law, caused by the fear, on the part of Parliament, of encroaching on the liberties of the people, was, that the offences enumerated as subjecting the offender to trial by courts-martial could only be committed on board ship. If committed on shore, even in a foreign country, the offender was to be brought home and held by the common law, or if in a British colony, to be tried by the common law of the place. In 1720 the jurisdiction of courts-martial was extended by making seamen and others amenable to naval laws for all offences committed on shore in foreign parts. During the reign of James II the navy was improved both in matériel and discipline. As Duke of York the navy had been his especial province, and on his accession to the throne he retained the personal direction of its affairs, refusing to appoint any Lord High Admiral. There was no legislation, however, in regard to it until the second year of the succeeding reign, when a question arose as to whether the acts of the Commissioners (now known as the Lords Commissioners of the Admiralty, or more commonly as Lords of the Admiralty), whom it had become the custom to appoint in place of the Lord High Admiral, were strictly legal. An act was therefore passed† confirming their authority, and giving them the same prerogative, in relation to the calling together of courts-martial, as had pertained to the position of Lord High Admiral.‡ During this reign also for the first time were laws enacted for the maintenance and discipline of a standing army in England. Soon after the accession of William III, France declared war against the States General. England, by the treaty of Nimegnen, was obliged to furnish a certain number of troops to aid the States in their defensive operations. Preparatory orders were given which some

* This law was drawn up by Admiral Montague, afterward Earl of Sandwich, and was approved by the Lord Chancellor and others of the King's Council, before it was submitted to Parliament.

| In this act was the first provision made for an oath to be taken by members of a court. It reads, "You shall well and truly try and determine the matter now before you between our Sovereign Lord and Lady, the King's and Queen's Majesties, and the prisoner to be tried; so help you God." This oath was administered by the Judge Advocate.

‡ 2d William and Mary, c. II. "An act concerning Commissioners of the Admiralty."

regiments refused to obey; their disaffection soon changed to open mutiny, and deposing their officers they elected leaders and marched towards Scotland. They were pursued by several of William's Dutch regiments, were forced to surrender, and were brought back to London. Parliament now saw the necessity of having some stringent regulations to control the troops that the unsettled state of the continent rendered necessary for the security of the country. A bill was passed (April, 1689) assigning death, or such other punishment as a court-martial should adjudge, for desertion or mutiny. An amendment was added which is of interest as an example of the customs and habits of the time. It was provided that no sentence of death should be passed except between the hours of six in the morning and one in the afternoon. The dinner was then early, and hard drinking being one of the qualifications of a gentleman, it was not supposed that any member of a court-martial after dining would be in a state in which he could safely be trusted with the lives of his fellow-creatures.* The first mutiny bill was passed for six months; at the end of that time it was renewed, and soon the army, being an established and necessary part of the government, the prejudice against it died out, and the bill, with the exception of three years, 1698 to 1701, was passed annually.

The next legislation with regard to courts-martial was under George II,† when an act was passed, "for supplying and remedying certain defects, and for maintaining a proper and strict discipline of his Majesty's Navy, wherein at all times, and more especially in time of war, the wealth, strength, and safety of these kingdoms are so much concerned." By this act the Commissioners were allowed to delegate the authority of ordering courts-martial, to Flag Officers and Captains, and it was stipulated that the officer ordering the court should in no case preside. Four years later, another act was passed, reducing into one act all these different laws and making them clearer and more consistent.‡ In this act the manner of ordering courts-martial is prescribed, and the number of officers serving on them is fixed, as we have it at present, at not less than five nor more than thirteen.|| One

* Macaulay's Hist. c. XI.

† 18 Geo. II, "An act for the regulating and better government of his Majesty's navies, ships of war, and forces by sea, and for regulating the proceedings upon courts martial in the sea service."

‡ 22 Geo. II, c. 23.

|| In the English service now (Act 1866) the number is fixed at not less than five (5) nor more than nine (9), and the court must be held on board a man-of-war.

peculiar, and it must have been inconvenient, clause of these regulations was, that after the beginning of a trial, the court should sit from day to day, and that no member should be allowed to go on shore until after sentence was given, unless in case of illness the court decided to excuse him. This clause remained in effect until after the trial of Admiral Keppel in 1779. This trial lasted for over five weeks, and the health of the members of the court was so affected by their protracted confinement, that they protested against the custom in a letter to the Admiralty.*

The oath heretofore prescribed, both for the members and for the Judge Advocate of a naval court, was so worded as to be productive of trouble and to cause warm debates on the subject in Parliament. The part objected to was a concluding clause, by which the members and the Judge Advocate swore not to disclose the vote or opinion of any member of the court, unless required to do so by act of Parliament.† It was now enacted that members of any naval court-martial should swear secrecy, unless required to give evidence before a court of justice in due course of law, and the oath was accordingly modified, in this respect, to the form we now have it.‡ By this same law, discretionary power was taken from courts-martial, by a clause which afterwards (1757) became the subject of the controversy arising from the famous trial of Admiral Byng, and was the legal excuse for the sacrifice of a gallant officer to the malevolent clamors of popular fury. By the original law of Charles II, the punishment for those who "should withdraw, keep back, or not come into fight," etc., was death, or such other punishment as a court-martial should adjudge. The act of 1749 made the penalty death, and in the trial of Admiral Byng this was the only punishment that could be adjudged; the members of the court, however, were unanimous in considering his offence an error only of judgment, and in recommending him to mercy. As this trial and execution were the cause of the re-alteration of this article in the ensuing reign, a brief description of the circumstances connected with it may be germane to our subject. Vice-Admiral Byng had been ordered to relieve the Castle of St. Philip, in Minorca, then about to be besieged by the French. His fleet, on arriving off the island, had an ineffectual skirmish with that of the French, in which the second in command, Admiral West, was quite

* In consequence of their representations, the act of 19 Geo. III repealed the obnoxious clause.

† 2 William and Mary, c. 2.

‡ 1749–50, 22 Geo. II.

briskly engaged for a short time, but finding that his chief did not come to his assistance or appear to desire a general engagement, he sheered off and the two fleets separated. After this it was decided that the relief of the place was not feasible; the object of the expedition was accordingly abandoned and the fleet bore away for Gibraltar. Here both Admirals were relieved and sent home. On arriving, Admiral Byng was tried by a court consisting of four Admirals and nine captains, who unanimously agreed that his offence, as charged, came under the article referred to, and as that article positively prescribed death as a punishment, no other alternative was left them than to adjudge that penalty. In addition to the recommendation to mercy, a letter was written and signed by all the members of the court, in which they called the attention of the Admiralty to the great severity of the article, and implied that the Admiral's chief offence had been an error of judgment. In consequence of this letter, one from Rear-Admiral West, who had been his second in command, and the efforts of Admiral Byng's family, the case was submitted to twelve judges for their opinion. They held that the sentence was a legal one, and a warrant for his execution was accordingly issued by the Admiralty. One of the Lords of the Admiralty, Admiral Forbes, refused to sign the warrant, and wrote a strong remonstrance against the execution, maintaining that the offence did not fall under the article prescribing death, and that therefore the sentence was illegal. All endeavors, however, were unavailing, and Vice-Admiral Byng was shot on the quarterdeck of the Monarque, on the 14th of March, 1757.* In the succeeding reign, the article under which he was condemned was amended, so as in all such cases to allow a discretionary power to the court-martial. The same changes were made in a similar article in our own country, as we find by examining the legislation of Congress. The first law for the governance of the nucleus of a navy, authorized by the Continental Congress, was that of the 6th of May, 1778, when it was resolved, "that if two or more vessels are in company, and any or either of them is lost, there shall be a court of inquiry, and if it should appear that the loss was occasioned by negligence, then a court-martial shall be held upon the commanding officer, and if it is proven that the loss was occasioned by cowardice or treachery by withholding his assistance from the ship so captured, then such captain shall suffer death; but if loss happened

* Smollett's Continuation of Hume, Vol. III.

through any other malconduct of such officer, then he shall be cashiered."* In the following August it was resolved, that the respective Navy boards, which at that time managed the Navy, should be authorized to carry out the above resolution according to the law martial, and that this power should last until the 6th of May, 1779.† On the 28th of October, 1779, a board of Admiralty was established, and all powers for the governance of the Navy, ordering of courts-martial, etc., were vested in them, together with the Marine Committee of Congress.‡ By a resolution of a month later, Judge Advocates were authorized, and it was recommended to the executive authorities of the States to compel the attendance of witnesses before courts-martial.§ In the succeeding year, 8th of February, 1780, it was enacted that the naval courts should consist of such officers, if conveniently to be collected, as by the rules of the Navy constituted a court-martial; otherwise, of five such persons as should be appointed by the Navy board.|| A Secretary of Marine was soon after authorized,¶ and all powers that before that time had been vested in the Navy boards and board of Admiralty were transferred to him, and he was ordered to transmit to Congress the proceedings of any court-martial, previous to the execution of any capital sentence.** On the 12th of June, 1782, it was provided that, for all capital cases, courts should consists of at least five commissioned naval or marine officers, two of whom should be Captains in the Navy, and in cases not capital, of three such officers, one of whom shall be a captain. At the same time any captain of a vessel was authorized to appoint a court-martial for the trial of offences committed by any other than a commissioned officer, but it was provided that all courts held on a commissioned officer should be ordered by the Secretary, or Agent of Marine When the War Department was organized,†† the Secretary of War was authorized to take charge of everything relating to the naval as well as the land forces, and it was not until the 30th of April, 1798, that the Department of the Navy was established, and the Secretary of the Navy empowered to enter upon the duties of his office, and to take charge of the records, documents, etc., pertaining to the service, which at that time were deposited in the office of the Secretary of War. The Navy Department now being established, it was natural that the

* Journals of Congress, Vol. IV.

† Journals of Congress, Vol. IV.

‡ Journals of Congress, Vol. V.

§ Journals of Congress, Vol. V.

|| Journals of Congress, Vol. VI.

¶ February, 1781.

** Journals of Congress, Vol. VII.

†† 7 August, 1789.

service should be more regularly governed than it had been by the desultory legislation we have noted, and a code of articles was formulated and authorized by Congress.* These were substantially a transcript of the English regulations; by them it was ordained that courts-martial were to be composed of not less than five, nor more than thirteen members, who were to be chosen from the grades of Commanders of Squadrons, Captains, and Sea-Lieutenants, none of whom should be junior to any officer for whose trial a court should be ordered. In taking the oath the Judge Advocate was to swear not to disclose the vote or opinion of any member of the court, unless required to do so by act of Congress, but there was no oath of secrecy so far as the members of the court were concerned. By these articles courts-martial were allowed a discretionary power in all cases that before this time had been regarded as capital. They were also empowered to imprison in cases of contempt of court or refusal to give evidence.

In the following year another act was passed substituting a more complete code of articles.† Those prescribing the composition, oaths, prerogatives, etc., of courts-martial are the same as are enjoined by the present law. The court consists of not less than five nor more than thirteen members,‡ with the senior officer presiding, and in no case where it can be avoided are more than one-half, exclusive of the president, to be junior to the officer to be tried. The oath of secrecy is taken by members § as well as by Judge Advocate, but with the provision that it may be disclosed, if required by a court of justice, instead of the necessity of its being authorized by Act of Congress, as was prescribed by the former law. In accordance with the custom obtaining in the service of the mother country, courts are enjoined to sit from day to day, and no member is allowed to absent himself, except in case of illness, and then on his return all evidence that may

* 2 March, 1799. These articles had been prepared by a board consisting of Captains Barry, Truxton, Dale, and Tingey. † 23d April, 1800.

‡ Who can be commissioned officers of any grade.

§ "I, A. B., do swear (or affirm) that I will truly try, without prejudice or partiality, the case now depending, according to the evidence which shall come before the court, the rules for the government of the navy, and my own conscience; and that I will not by any means divulge or disclose the sentence of the court until it shall have been approved by the proper authority, nor will I at any time divulge or disclose the vote or opinion of any particular member of the court, unless required so to do before a court of justice in due course of law."

have been given in his absence is read over in the presence of, and acknowledged by, the witness who gave it.

The conception of courts-martial as courts of honor as well as courts of justice is acknowledged by the great limitation given by the clause, "or such other punishment as a court-martial may direct," which is the ending of so many of the articles prescribing penalties for certain offences. All sentences extending to loss of life require the concurrence of two-thirds of the members present,* and together with sentences of dismissal of a commissioned or warrant officer, must be approved by the President of the United States.

The summary court of three members for the trial of minor cases was established in 1855,† the idea being to have in the navy a court similar to the regimental courts-martial of the army.

We have thus attempted to trace the gradual development to our present form of trial. Much that cannot be followed, was doubtless the result of usage and customs of which we have no record, and of which the legislation of past years gives us only a speculative clue. The number of members prescribed by each successive law, and their filling the position of a jury as well as that of judges, shows the influence of a custom so old that it is said to have originated with the ancient Greeks—that is, the method of a trial by a jury of twelve men or twelve votes. The custom of the youngest or junior member voting first originated in France,‡ and was adopted by the English a few years before the American revolution. The French manner of voting was the same as our own—that is, the junior member of the court recorded his finding on a piece of paper, and, folding it over so that the vote was concealed, handed it to the presiding officer. The reason for this is, of course, patent to every one. The junior in rank was usually a younger man than the others of the court, and, lest he should be influenced by their more mature judgment or affected by their higher rank, he was obliged to vote first. That the form and ceremony of courts-martial are derived from that of the ancient courts of chivalry there seems to be no doubt. Although between the two there is a lapse of years in which no legal provision is made for military trials, yet, as both land and sea forces were maintained during that period, there must have been some unwritten code of laws for the trial and punishment in time of war—if at none other—of grave offences; and when courts-martial were established by the act written

* Acts 23 April, 1800, 17 July, 1862.

† Act of 2d March, 1855.

‡ Bardet de Villeneuve, Cours de la Science Militaire, Tome I, p. 64.

by the Earl of Sandwich, he in inditing it, was doubtless guided by these same unwritten customs of the service to which he belonged. Let us hope that our courts-martial are not the only legacy left us by the age of chivalry, but that we have also succeeded to the virtues and high principles of that institution, and that the lax and pernicious opinions that now obtain to such an alarming extent may never invade our body, but that, like the last of the chevaliers, it may always be "sans peur et sans reproche."

DISCUSSION.

THE CHAIRMAN.—I have listened with great pleasure to the lecturer, and hope that his reminder of the source from which Courts-Martial have been evolved will be of value to the service. That such a reminder is necessary must be apparent to all those interested in the discipline of the service, who have watched the proceedings of our courts during the last few years. If this historical study had been before their eyes, and had they remembered the weight of military precedent and the custom of war, could any body of officers have found that it was not ungentlemanly and unofficer-like conduct for one of their service to refuse to pay his debts? Yet this has been done in our own service, and in the army it has been held by their highest authority in military law that the failure to pay debts was not a military offence, and, still further, that a man placed on guard over a prisoner who fired at or towards said prisoner committed no offence against military law. If such opinions are well held, military law is shattered to its foundations, and all offenders should be turned over to the police courts.

It *has* been considered established law that a military man might, by one act, commit an offence against both the civil and military law, and might be tried under both, provided he was not twice placed in jeopardy of life and limb. Starting from this point, it may be well to see in what way a military offence may differ from one purely civil. This is explained by Macaulay in a few lines on the Mutiny Act, referred to by the lecturer. In these he shows the necessity of military laws and trials by courts-martial, with his usual clear and concise language. The man who gave to India one of the best criminal codes known to the world must have been a good judge of such a subject. But as the lecturer has treated our military law as under the theory of evolution, let us look at it with the light of the laws belonging to that theory. First find to what period of social evolution our military societies are most closely related, and then find what was the character of laws which best coincided with the condition of society in such a period. At a time when all men carried arms, good order was only maintained by severe laws.

Our courts have improved as the bodies to be governed have improved. An accused is no longer forced to plead. He is allowed counsel, his counsel is allowed more latitude, and he is even allowed to testify in his own behalf; but this has not been sufficient for some, who fail to recognize that there is a necessity for more rigid laws and more summary punishments in military than

in civil government. The modern tendency is to break down all barriers, and to turn courts-martial into police or criminal courts, and even to still further weaken their authority by reviewing their findings not only in points of law, but also in points of fact. Not only have their findings but little weight on points of law (although they should be good authorities on points of military precedent and the custom of war—the common law of the services), but the modern tendency is to place those composing the court below the average jury, and to give little weight to their findings on facts established by witnesses testifying in their presence. Those reviewing will show how little faith they put in the capacity of the court by reversing their findings, which were dependent not only on the words of the witness as recorded, but also on his tone, his manner—on *all* that enables men to judge whether a witness is truthful, or whether his words are but a disguise to his thoughts—by reversing their findings as to facts by a review of the *written* testimony.

There are two extreme classes among those having to do with courts-martial—some who would have no other guide but their own opinions, and others who would follow exactly the civil courts, and, when obliged to decide upon a point for which they have no precedent, seem obliged to avoid not only military law but also common sense. As usual, the middle course is the true one. While a knowledge of law is necessary in construing statutes, in framing questions and examining witnesses, and by following the rules of evidence as established by common and statute law, the proceedings are facilitated and the court guided in forming just conclusions—on the other hand, the ordinary procedure of the civil law is too tedious and lengthy for military tribunals. To maintain discipline, the punishment for an offence must be weighty and the proceedings summary. Long arguments, minute cross-examinations, large masses of documentary evidence, quibbles on points of law, lengthen out the proceedings, and if allowed before courts-martial, would destroy their usefulness and undermine discipline.

But to those interested in the subject so ably treated by the lecturer, the saddest sight of all must be that of the Examining Board. Originally constituted as a High Court of Honor, of whom the statute says, "Until the mental, moral and professional fitness have been established to their satisfaction," no limiting clause but their oath of office, no limiting law but their own conscience, now so bound down by decision after decision upon points raised by those of whose fitness they were not satisfied, and argued only on that side, until they present a spectacle remarkably like a county examination board for a country school—barrier after barrier erected against the proper performance of their duty, until they are required by decisions and restrictions to be satisfied, when by precedent, by the laws under which they are constituted and by their own common sense, they must be thoroughly dissatisfied, disgusted and disheartened.

It would be well for us all to remember the embryo from which our courts were evolved, and that, besides statute law and the common law of the land, we have a common law of the service—that old and well-established precedents should only be reversed after most careful deliberation, and new precedents established only after mature consideration.

NAVAL INSTITUTE, WASHINGTON BRANCH.

JUNE 7TH, 1883.

COMMANDER WM. T. SAMPSON, U. S. N., in the Chair.

WATER-LINE DEFENCE AND GUN-SHIELDS FOR CRUISERS.

By PASSED ASSISTANT ENGINEER N. B. CLARK, U. S. N.

"An examination of facts is the foundation of science."

A well designed war-ship may be termed an aggregation of compromises. The augmentation or extension of any quality beyond a certain limit can only be made at the expense and by the curtailment of some other requisite, equally, or perhaps more, desirable.

Everything has weight, and to carry weight requires displacement, which involves increased resistance and greater engine power. The distribution of weights so as to produce the best general results is a problem of the greatest importance, for upon it depends the success or failure of the vessel, as measured by the standard of comparison with others.

The cardinal requisites of a war-ship, mentioned in the order of their importance, are:

1st. Defensive power—ability to keep the ship afloat, and the crew alive.

2d. Offensive power—ability to destroy or disable an enemy's ships and men.

NOTE.—No. 25, Proceedings U. S. Naval Institute, "The Development of Armor for Naval Use," by Lieutenant E. W. Very, U. S. N., a member of the Naval Advisory Board, having been published after this paper, in its original form, was read before the Washington Branch (June 7, 1883), has necessitated some revision and additions by the author, to correct certain statements by Lieutenant Very in relation to the curved shield, which are herein claimed to be erroneous.

3d. Mobility—power to chase down or ram an enemy.

4th. Quarters—giving healthful and sanitary accommodations to officers and men, necessarily conducive to proper morale and discipline.

Of these prime requisites, defence of the water-line is, to a war-ship, a matter of paramount importance; for even though a vessel had the speed of the wind, was armed with the most powerful guns, commanded by the most capable officers, and manned by the bravest crew, all would avail nothing if she could not be kept afloat in combat.

The great improvements attained in the rapidity of manipulation, accuracy of fire and range of the modern breech-loading rifle guns, make the defence of the water-line a matter for the most serious consideration. Percussion shells of large size, each one of which is in itself a mine, will render an efficient defence of the water-line a problem very difficult of solution. But even if absolute protection cannot be attained, the importance of the matter demands the adoption of every available expedient that may lessen the chances of fatal disaster and ensure the flotation of the ship—1st, by keeping the water out, as far as possible; 2d, by freeing the vessel of water, should it unfortunately gain entrance.

A water-line defence, consisting of armor disposed vertically, is at the mercy of *elongated* shot, concentrating their energy on the small area of their cross sections; and if such armor extends the length of the vessel, the bow and stern are encumbered with a weight entirely disproportioned to its flotative power.

Vertical side armor does not give an efficient protection, unless supplemented by deck-plating; but if the aggregate weight of the vertical armor and deck-plating is distributed over the vessel in the form of a curved shield, having a cross section conforming to the arc of a circle, extending across from side to side, and so placed within the ship as to have its crown slightly above the water-line, with the sides attached to the vessel some four feet below it at ordinary load draught, a much greater measure of protection can thereby be obtained with the same weight of armor; as elongated shot strike it upon their sides, thereby presenting the much greater area of their longitudinal sections, by which they would be deprived of much of their penetrating power. Moreover, the glancing effect of a curved shield will enable a comparatively light plate to throw off a heavy shot.

The zone of danger is the side of the vessel, alternately acted on by wind or water as the ship rolls. It is proposed to protect this vital

part by interior deflecting armor; the position of the shield in relation to the water-line to be adjusted by the admission of water to the double bottom.

In combats between ships at ordinary fighting range, horizontal fire is all that need be considered; a vertical target can easily be struck, while it is almost impossible for a projectile fired from a vessel rolling at sea to strike a horizontal surface. Under such circumstances it would be very difficult to land a shot upon the area of a hundred-acre farm, to say nothing of the much smaller surface of a ship's deck. Curved fire from land batteries placed for the defence of channels is most effective, but such fire is impracticable in contests between vessels at sea, as an entire shipload of ammunition might be expended before making one successful shot.

When elongated shot fired from rifled guns strike the water, they tumble end over end and sink beneath the surface, and there is probably no instance known of such a shot striking a vessel below the water-line, unless her side was exposed by rolling. When the combatants are a certain distance apart, the intervening water serves as an impenetrable rampart for that portion of the ship below its surface. For every depression below the mean level of the water there is a corresponding elevation or protuberance above it; and these elevations or protuberances above the mean surface will most effectually deflect shot of high energy, and protect the side of the vessel below them; therefore, a vessel would not be exposed by the hollows between two waves, and if she was, a plane-sided shield would have no advantage over a curved one.

Referring to the drawings, Figure 1 is intended to illustrate the great superiority of the curved deflective shield over any other form of armor for water-line defence, in that it conforms to the arc of a circle in cross section, and presents, as the ship rolls, a practically constant angle of impingement to horizontal shot.

The portion of a deflecting shield, of any form, liable to be struck at any given instant consists of a zone of small area situated above, at, and very slightly below the mean water-level. This small zone is shifting in character, and on a curved shield of five feet rise, extending four feet below and one foot above the water-line, it would probably be about 18″ in height. The curved shield covers the entire zone of danger, five feet in height; and this smaller zone, consisting of the part liable to be struck by horizontal fire at any given instant, traverses the larger zone more or less, according to the oscil-

lations of the vessel, and protects it in detail by constantly presenting a great horizontal thickness of armor, with a very acute angle of incidence, and a very large angle of clearance to the part where the vast majority of shot strike.

Figure 1 represents a cross section of a cruiser, and three different forms of deflecting shields, numbered respectively 1, 2 and 3. They each have the same immersion, being secured to the sides of the vessel four feet below the water-line, and nos. 1 and 2 rise one foot above it; but the angle of the plane-sided shield no. 3 being equal to the angle of incidence of the curved shield no. 2 at the water-line, does not carry it to the same height.

No. 1 is the plane-sided shield proposed by the Naval Advisory Board for the cruiser Chicago, being the fac-simile of the official drawing. This shield presents so large an angle to horizontal shot at the water-line that it will afford no adequate protection with the light plating of 1½ inches proposed. Besides presenting too large an angle to give protection, it also weighs considerably more than nos. 2 and 3.

No. 2 is the curved deflecting shield—the form of water-line defence recommended by Act of Congress of August 5th, 1882, authorizing construction of new cruisers—conforming in cross section to the arc of a circle, and presenting a practically constant angle of impingement to horizontal fire at the water-line as the ship rolls, and that so acute as to make penetration very difficult with comparatively light plating.

A horizontal shot at the water-line would strike the curved shield at *G;* as the line *IT* is tangent to the arc at the point of initial impingement, it therefore represents the angle of the same.

The fact being that more shot would strike the curved shield above the water-line than below it, it is therefore making a concession to take *G* as the average angle, as, practically, the mean angle would be much less; and it should also be remembered that *G* is the initial angle of impingement, which, owing to the curved surface, rapidly diminishes as the shot glances along the plate. Such a curved shield would therefore possess a much greater deflecting efficiency than a plane-sided one, presenting the same angle of impingement, like nos. 1 and 3, the angles of which would not decrease as the shot glanced along their surfaces, but would be liable to buckle up in front of the shot and be pierced by it; a contingency that would not arise with the curved shield, presenting the same angle, as the shot, owing to the curve, can much more easily free itself from the surface of the armor.

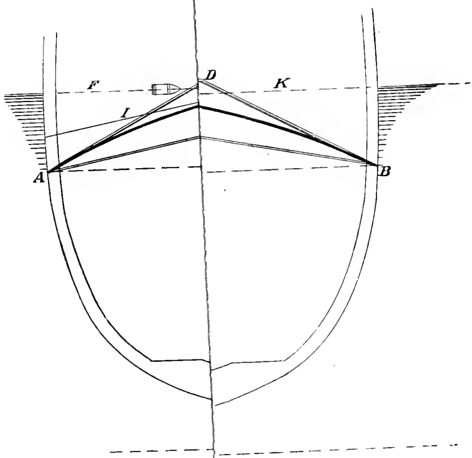

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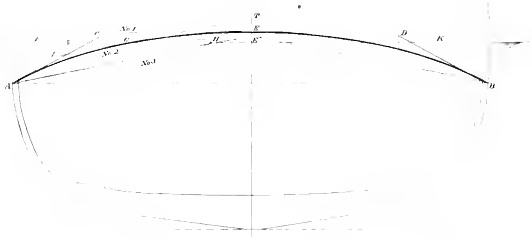
Fig. 1.



Shield no. 3 is drawn for the purpose of proving that it is impossible to construct a shield, having plane inclined sides, that will present so acute an angle to horizontal fire as the curved shield no. 2; or that will give as much room under it for boilers and machinery; or that will exclude the same amount of water from the part of the vessel above it; or that will give the same strength and stiffness to a vessel.

The line AE' is drawn parallel to the tangent IT, and the horizontal water-line cuts it at H. As the line AE' is drawn parallel to the tangent IT, therefore the angles G and H are equal. And as this angle will not carry the crown of the plane-sided shield to the same height as the crown of the curved shield, the plane-sided shield will require a greater angle to attain the same height.

It will be apparent that the curved shield no. 2 contains under it the space represented by the segment contained between the arc AGE and its chord AE', in addition to that contained under the plane-sided shield no. 3.

Also as the segment is above no. 3 and below no. 2, the former will admit a volume of water into the ship above it, equal in cross section to the area of the segment $AGEAE'$, to endanger the buoyancy and stability of the vessel, which the round-up of the curved shield no. 2 would exclude.

The curved shield no. 2 is superior in these particulars to the plane-sided shield no. 1, or any other plane-sided shield, presenting the same angle, that can be constructed:

1st. It presents a more acute, and, practically, constant angle of impingement to horizontal fire, and one that with a moderate thickness of plating, if supplemented with coal or stores in water-tight compartments to augment the deflecting efficiency and exclude water, would afford a very substantial resistance to the fire of heavy guns, while the plane-sided shield would afford but a very small measure of protection.

2d. The plane-sided shield no. 1 would weigh considerably more than the curved shield no. 2, and would encumber a ship with the weight of armor without giving her the benefit of its protection.

3d. The curved shield, if anything like the same angle of impingement is presented, will contain much more room under it, for boilers and machinery, than an inclined plane shield, and is therefore admirably adapted for light draught vessels intended for service in the shoal waters of our Atlantic and Gulf coasts.

4th. With an equal angle of impingement, the round-up of the curved shield would exclude a large volume of water, which the plane-sided shield would permit to enter, and endanger the buoyancy and stability of the vessel.

5th. The curved shield will possess a much greater deflecting efficiency with any given angle, owing to the fact that the angle of clearance is a constantly increasing one, so that projectiles which would readily pierce a plane-sided shield can free themselves from the surface of the curved shield.

6th. The curved shield, tied in by the chords of its arc and supported on longitudinal and transverse bulkheads, in combination with the ship's cellular bottom and sides, will give a vessel an efficiency and strength as a ram that is unprecedented. A vessel so built would form a scientifically constructed floating girder, having such rigidity as would permit of her being engined with the highest power. The curved shield with coal or stores above it, to augment the deflecting efficiency and exclude water, thereby serving as a life-belt for the vessel, would make a ship almost unsinkable, while the plane-sided one would be such an element of weakness that a vessel fitted with it could only with difficulty be kept afloat in action.

In regard to the deflecting efficiency of light plates, disposed at an acute angle, the British Admiralty have made experiments at Portsmouth within the last two years for the purpose of testing deck armor, proving that a two-inch iron plate, entirely unbacked, simply supported on beams, disposed at an angle of 10°, would resist the penetrating power of the 18-ton 10-inch gun; and that iron plates of three inches thickness, similarly placed, and disposed at an angle of 15°, would throw off shot from the same gun discharged from a distance of 100 yards.

If such good practical results can be obtained from iron plates, it is reasonable to expect that a much greater efficiency can be derived from homogeneous steel plates, combining hardness with toughness.

To determine the relative deflecting power of the curved and plane-sided shields in the absence of any very extensive experiments on inclined plates, we can only reason from results obtained with vertical armor, and, hence, to form a fair comparison it is reasonable to suppose that in all cases the velocity of the shot, resolved in a direction normal to the plates, is entirely destroyed, and that the striking force in each case will be that due to a shot of the same weight moving normal to the plate with a velocity equal to the normal velocity of the shot moving obliquely to the plate.

The penetrating power of the shot being measured by its intrinsic energy, or by $\frac{w.v^2}{2g}$, then, on inclined plates the striking force would be $\frac{w.v^2 \sin^2\theta}{2g}$, where θ is the angle between the direction of the shot and the tangent to the plate at the point of contact.

In the diagram, Figure 2, draw the tangent to the curve at the water line, and lay off on the horizontal line a distance AO to represent v^2, draw AC parallel and OC normal to the tangent OT; lay off OB equal to OC, drop the perpendicular BD, then OD

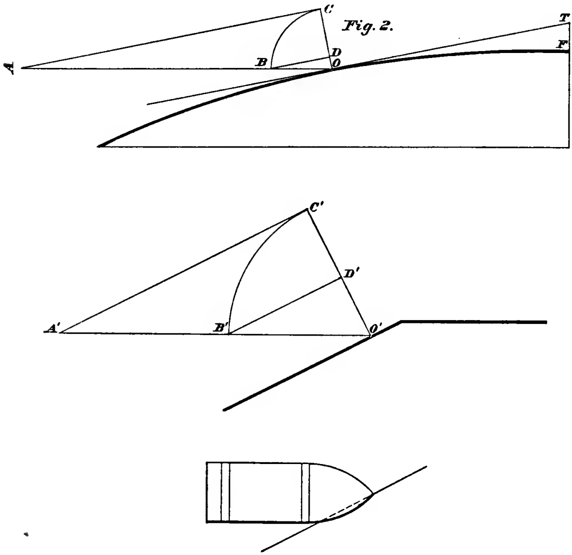
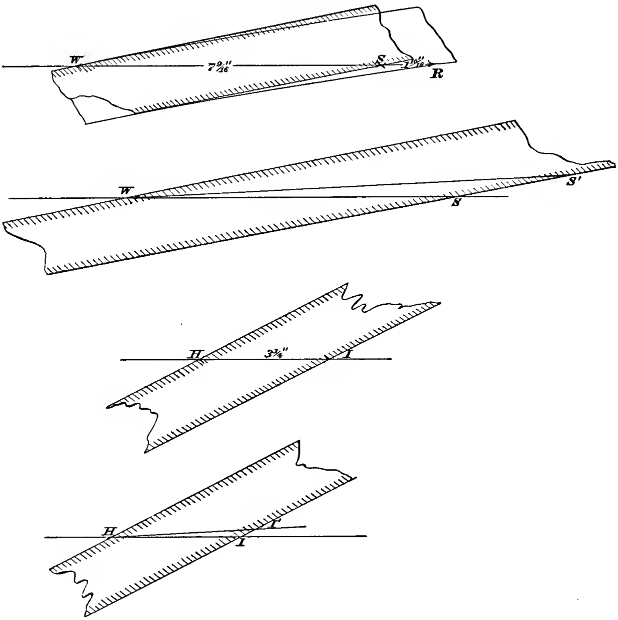


Fig. 2.

will equal $v^2 \sin^2\theta$, θ being the angle of inclination of the tangent to the horizon. Proceeding in the same way with the plane-sided shield, denoting the corresponding lines by corresponding letters, $O'D'$ will equal $v^2 \sin^2\theta'$, where θ' is the angle of inclination of the plane-sided shield to the horizon. The striking force exerted against the shields

respectively will be represented by these lines multiplied by the same constant, and the relative protection afforded will be inversely as the lines, or as 5.4 to 1 in favor of the curved shield. But when it is taken into consideration that the curved shield allows the projectile to clear itself after striking, by a considerably increasing angle of clearance, between the curve *OF* and the tangent *OT*, it is evident that this ratio of protection will be considerably increased in favor of the curved shield.

Fig. 4.



The other method of comparing the relative efficiency of the two shields is to measure the metal that would have to be displaced to effect penetration. In the case of the curved shield the distance through *WR* is $9\frac{3}{16}''$, there being $1\frac{10}{16}''$ greater distance through the metal of the curved shield than through a plane-sided shield present-

ing the same angle. The distance *HI* through the metal of the plane-sided shield no. 1 is only $3\frac{1}{4}''$.

In the case of vertical armor, experience has demonstrated that the energy required to penetrate plates of different thickness is proportional to the square of the thickness of the plate; and reasoning from this, we are led to conclude that in the case of inclined plates it will vary as the square of the distance measured through on a line making the same angle with the plate that the plate makes with the horizon.

Taking the shield before mentioned, the distance through, as measured on the water line, in the case of shield no. 1, is $3\frac{1}{4}$ inches, and in the case of shield no. 3 the distance measures $7\frac{10}{16}$ inches, and the efficiency of the two shields would be directly as the squares of these quantities, or as 1 to 5.4. But as the curved shield allows the shot in glancing to clear itself more readily than a plane shield, it will be much more efficient than the above proportion shows.

Notwithstanding the fact that the great superiority of the curved shield over the plane can be proved by unanswerable mathematical demonstrations, Lieutenant Very, in his able and interesting article, "The Development of Armor for Naval Use" (No. 25, Proceedings U. S. Naval Institute), takes peremptory ground in favor of the plane over the curved shield: but I propose to show that both his premises and conclusions are erroneous.

On page 527 will be found this statement in reference to the comparative merits of the two shields: "In the United States it has been made a matter of much discussion whether this alteration from a curved to an angular disposition is an improvement or a step backward. It seems, however, to be easily susceptible of proof that the angular arrangement presents most decided advantages." Upon the same page is a diagram representing a curved and a plane shield on the same cross section, with the outline of a boiler in position under them, for comparison. The top of the plane shield is represented as entirely below the water line, while the crown of the curved one rises far above it; but fairness of comparison in boiler capacity, under the two shields, required that both should have been given the same vertical height.

A casual, or an unscientific reader, from "a great respect for official utterances," might give this unqualified claim of "most decided advantages" of the plane over the curved shield, its face value, but a critical examination of the diagram with its explanatory context will show the claim to be unfounded. It is generally true that any theory

is "easily susceptible of proof" where its advocate is allowed to make his own premises, but Lieutenant Very has failed even to draw correct conclusions from his voluntary assumptions.

The only special advantage claimed by Lieutenant Very—with the aid of his incorrect diagram—which can be conceded, is a very slight decrease of angle of the plane over the curve at a point four feet below the water line, where projectiles virtually never strike. But when it is considered that this slight disadvantage for the curved shield, at the point mentioned, is accompanied by a corresponding decrease of the angle of curve over the plane at the top of the shield, where essentially all projectiles do strike, this very slight advantage is conceded, admitting for this argument Lieutenant Very's delusive diagram. I am not advocating protection to that part of a ship where it is practically invulnerable to shot.

There have been winds so fierce as to destroy the strongest structures on shore, and there have been storms so violent as to founder the staunchest ships at sea, and lightning so powerful as to make sport and fragments of either. Against such unusual incidents, intense as is the love of life, it has not been within the power of human thought adequately to provide. If men should seek to do it they would never build ships nor houses, but live in caves, and then not be absolutely safe from these immeasurable and irresistible forces. Such dangers are the inevitable risks of our living at all, and we build ships and go to sea in them, and build houses and live in them, and take these risks, and we would be mere savages if we did not. In this category of extremely improbable chances would come the likelihood of a ship being struck by a projectile four feet below the water line during an engagement. Such a thing *may* happen, but experience shows that it is no more likely to occur than the disasters of nature mentioned above.

If the curved and plane shields, represented in the diagram on page 527, were correctly shown as of equal height, the advantage in weight would be in favor of the curved; but the advocates of the plane are welcome to the infinitesmal advantage in this respect apparently obtained by the diagram.

This drawing also contains the outline of a boiler in position under the shields, and the statement has been repeatedly made, by members of the Advisory Board, that the curved shield will not cover as great a height of boiler as the plane-sided one. This assertion is also incorrect, as an inspection of the diagram will show. If

the boilers are set close out against the side of the vessel, no advantage whatever in height of protected space would be obtained by the curved shield, as the top of the boilers would have to be placed more than four feet below the water-line, the same as when placed below a flat, under-water, armored deck, similar to that of the Comus class. The top of the shield being placed below the water-line, if the sides of the vessel should be penetrated, then when the water-excluding stores are exhausted from the compartments above it, the Comus flat-deck would permit water to flow in and sink the vessel. The top of the shield should rise somewhat above the water-line in order to give the vessel a margin of buoyancy independent of the water-excluding stores.

If the boilers are placed part way out, in the position shown on the diagram referred to, only a small measure of protection is obtained by the shield, owing to the large angle of incidence presented.

But any one can see, by referring to the diagram on page 527, that if the boilers are placed in their proper position, in the centre of the vessel, the curved shield there represented will cover a much higher boiler than the plane-sided one. Lieut. Very, therefore, in constructing his diagram "builded wiser than he knew." Such a disposition of the boilers will give the following advantages over that shown in the diagram, viz. it will admit of a central longitudinal bulkhead, dividing the under-water body into water-tight compartments, a device with which all large vessels should be provided; it affords greater safety to the boilers from the attack of torpedoes and rams in time of war, and danger from collision; it enables the firemen to obtain coal from side bunkers, or chutes from compartments above, directly in front of their furnace doors.

A large proportion of the coal and stores should be carried in the compartments above the shield, the effect on the stability of the ship being compensated for, when occasion requires it, by the admission of water to the double bottom. This would allow nearly all the space under the shield to be utilized for boilers, fire-rooms, machinery and magazines, with passages from the same to the different guns. The stout tubes for training the vertical V shields by power applied beneath the shield, also serve as conduits for conveying ammunition directly to the breech of the guns. By this means all exposure of men by the transportation of ammunition along the open deck is avoided.

Lieutenant Very makes the following statement on page 529: "It has been shown heretofore that a thickness of armor for the shield of

less than four inches can scarcely be depended on at a greater angle than 20°. The average angle necessary for this shield is from 22° to 28°." These statements are strictly true, yet he, with a knowledge of these facts, proposed to apply $1\frac{1}{2}''$ thickness of plating to all the new ships in the form of plane shields disposed at an angle of 27°, having a horizontal thickness of only $3\frac{1}{4}''$, while a curved shield of considerably less weight, covering boilers of equal height, would present an angle of only 13°, and a horizontal thickness at the water-line of $9\frac{3}{16}''$, which would afford eight times the resistance of the plane.

An examination of the next statement on page 529 proves it to be widely incorrect: "Where a two inch deck curved with a single radius is put in, the same weight would allow with the chord disposition, 4 inch plates on the side chords and $1\frac{1}{2}$ inch on the dead flat." Taking the cruiser Chicago, the ship of greatest beam, and therefore the one most favorable for the above hypothesis, we find the area of the flat top is not more than one-eighth greater than the area of the side planes. It would therefore be impossible to increase the thickness of the side planes more than $\frac{5}{8}$ of an inch by taking a half inch from the flat top, although two inches are claimed. In the ships of less beam, Boston and Atlanta, a half inch taken from the flat top would not increase the thickness of the side planes as much as $\frac{5}{8}$ of an inch.

If the thickness of the sides of the plane shield can be augmented at the expense of the top, so likewise can the sides of the curved shield be increased in thickness at the expense of the top, by the application of taper plates; it is therefore not worth while to take this feature into consideration when comparing the merits of the two shields.

In a plane shield of such light plating as $1\frac{1}{2}''$, disposed at so large an angle as 27°, the resistance would be so small in comparison to the power of the guns likely to be brought against it, that the full effect of the horizontal distance through the plating would not be obtained; as the tendency, in such cases of disproportioned resistance to projectile force, is for the shot to turn in a direction normal to the surface of the plate, as there is a less thickness of metal under the projectile than above it, and passing through the plating it moves in the direction of the less resistance. Therefore, such a weak shield, aside from its affording no adequate protection, would be a positive source of danger in itself from the downward deflec-

tion of projectiles; while a curved shield of equal thickness and less weight, presenting a much more acute angle of incidence, with a constantly increasing angle of clearance, would invariably deflect shot upwards.

Figure 1 is a fair and correct diagram for comparing the merits of the curved with the plane-sided shield, as both are of the same height, each being secured to the sides of the vessel four feet below the water line, and rising one foot above it.

With such a curved shield as no. 2, Figure 1, of two inches thickness of plating, the horizontal distance through the plating on the water line would be 12.25″, and the angle presented at the same point would be 13°, while the horizontal distance through a plane-sided shield similar to no. 1, Fig. 1, of that same thickness of plating, would be 4.33″, and the angle presented would be 27°. This angle would of course be the same at all depths, and would be the average of the angles in all positions, which would sometimes be greater and sometimes less.

The horizontal angle of incidence of the curve would be practically constant in all positions, and the horizontal thicknesses of plating, and ratios of superiority of the curve over the plane at different points of immersion, would be as follows, viz.

	Horizontal thickness.	Superiority of curve over plane.
6″ above water line, . .	18.5″	18.31 to 1
water line, ...	12.25″	8 to 1
6″ below water line, . .	9″	4.32 to 1
12″ below water line, . .	7.75″	3.2 to 1
18″ below water line, . .	7″	2.61 to 1
24″ below water line, . .	6.25″	2.08 to 1
30″ below water line, . .	5.5″	1.61 to 1
36″ below water line, . .	5.25″	1.41 to 1
42″ below water line, . .	5″	1.33 to 1
48″ below water line, . .	4.75″	1.15 to 1

From the above list of horizontal thicknesses of plating, and ratios of resistance at different depths of immersion, it will be seen that one of the chief merits of the curve is that it keeps its greatest angle and least thickness of plating safely submerged at a considerable depth below the water line, where shot cannot strike it; but where protection is most required, the curved shield gives the greatest thickness of plating, the most acute angle of incidence, and the largest angle of clearance, automatically adjusting the same as the vessel rolls.

A curved shield of two inches in thickness, presenting an angle of 13° at the water line, and a horizontal distance through the plating of 12.25″, would give double the resistance of a plane-sided shield of 4″ thickness presenting an angle of 27°, and having a horizontal distance through the metal of 8.66″, as the squares of these numbers would be 150 and 74.99, or a ratio of 2 to 1 in favor of the curve, omitting the advantage of the large angle of clearance afforded by the curve; which also applies to all the ratios.

At the instance of Chief Constructor Theodore D. Wilson, who appreciates the superior merits of the curved shield, the Honorable Secretary of the Navy caused a modified form of it to be adopted in the plans for the cruiser Chicago. The plans for the Boston and Atlanta still contain the plane-sided shield.

The flat, under-water, armored deck applied to the Comus class of the British navy is in no sense a deflecting shield, as it cannot be struck by shot, being intended merely to resist the more direct downward impact of the fragments of shell, exploding within the vessel, above it. The Comus deck has no more curve than is given an ordinary deck for drainage, and it is so far below the water line that it does not give the room under it for boilers and machinery, which the curve, rising above the water line, affords; and, for the same reason, it does not give the margin of buoyancy which would keep the ship afloat in the absence of water-excluding stores.

The plane shield is a foreign modification of the curve, having been applied to the Leander class of the British navy as late as 1880; while the curved shield is a domestic product, having been designed by the writer of this article more than 20 years ago, when serving in Farragut's squadron; and was the result of his observation of the effect of shot on vessels in actual combat, and he asks no consideration for it on any ground other than its merits.

Figure 3 represents a cross section of a cruising vessel of 48 feet beam and 19 feet mean draught, in which the water line is defended by means of the curved deflecting shield no. 2, heretofore described, in combination with water-tight compartments above it to be packed with coal or stores, to augment the deflecting efficiency and exclude water, thereby serving as a life-belt to the vessel.

The cross section shown represents the compartments above the curved shield as packed with coal. The position of the curved shield in relation to the water line is to be adjusted before going into action, by the admission of water to the double bottom. The cellular sides of the vessel *BB*, between the curved shield *A* and the gun deck above

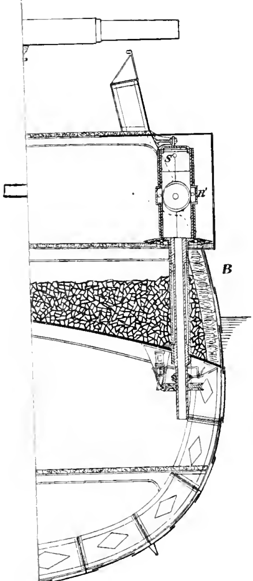

S
H'
B

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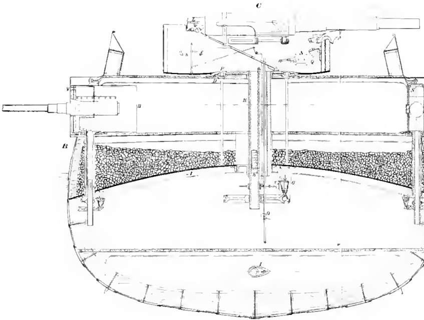
Fig. 3.



it, are represented as packed with cotton, chemically prepared to resist fire, which would, by its elasticity, close shot holes and exclude water.

Figure 5 represents the curves of reserve and decreased buoyancy, for the purpose of showing that a vessel having a curved deflecting shield, rising slightly above the water line amidships, and having water-tight compartments above it packed with coal or stores, covering and protecting the under-water body, could have the sides of the vessel above the shield completely open to the sea, without destroying her buoyancy.

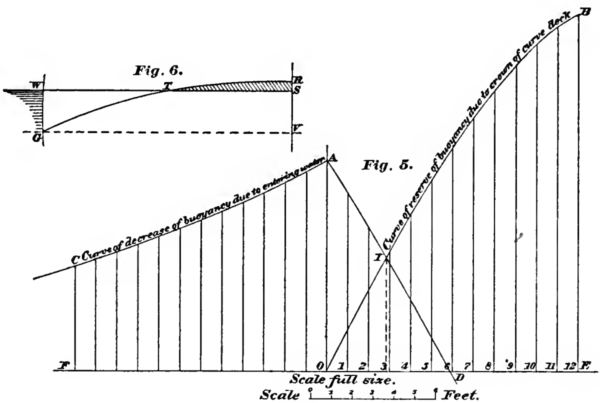


Figure 6 represents a cross section of a cruiser fitted with a deflecting shield rising one foot above the water-line amidships, and attached to the sides four feet below it.

We will now suppose the sides of the vessel to be shot through, allowing water to enter into all of the compartments comprising the space *GTR* over the shield, in which water-tight compartments coal and stores are packed, capable of occupying three-fourths the volume.

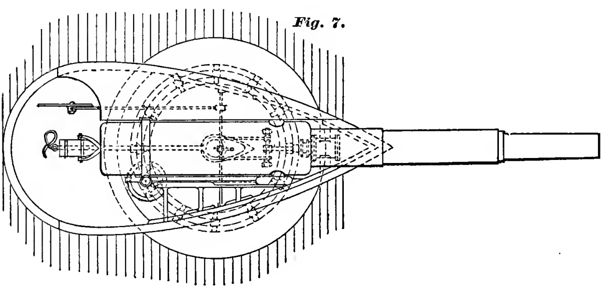
The water flowing in fills up the other fourth of the space *GWT* —which is interstitial—and when it has risen as high as the load water-line *WT*, the decreased buoyancy reaches a maximum equal to the weight of water filling one-fourth the space *WGT*, as shown on the curve by the ordinate *AO*. As the vessel sinks and the water continues rising in the life-belt of the ship—that is, the space above the water line and the curved shield—the stores in the life-belt displace a volume of water equal to three-fourths the space above the

load water-line and the curved shield; combining this increase of buoyancy with the decrease of buoyancy due to the water which has entered the space *WGT*, we obtain the curve *AD*, whose ordinate will represent the loss of buoyancy due to the entering water. As the vessel sinks, however, the curved shield is constantly increasing the displacement, and the ordinates of the curve *OB* will represent the increased buoyancy due to this increase of displacement. This curve intersects the former curve at *I*, at which point the upward and downward forces are again in equilibrium, and the abscissa corresponding to the ordinate at *I* will give the distance the vessel will sink by having her sides perforated completely above the shield, allowing water to enter freely all the compartments of the life-belt of the vessel. This abscissa is $2\frac{5}{8}''$, and the vessel cannot sink further without the curved shield being pierced, allowing water to enter below it.

In comparing the plane shield, having inclined sides, with the curved shield, the relative structural strength of the two should not be lost sight of. In the curved shield, strengthened by curved beams and having the space over the shield and the berth deck divided by bulkheads, greater lateral and transverse strength can be given a ship than can be attained in any other way.

We will next consider the most desirable forms and arrangements for deflecting shields for guns. These are not simply shields, but are in fact armored gun-carriages, the guns being supported and trained upon them. Referring to Figure 3, *C* represents a cross section of a vertical V gun-shield closed at the rear, with a $10\frac{1}{2}$-inch wire wound pivot gun mounted on it *en barbette.* Figure 7 represents a plan view of the same gun and shield.

Fig. 7.



This gun-shield is to be constructed of steel plates curved to the form shown on the plan view Figure 7, and disposed vertically to deflect sidewise shot that come from the direction in which the gun is trained. The gun has no lateral motion of its own independent of the shield, consequently when the gun is trained to deliver its fire, the shield is at the same time trained to the most favorable position to deflect shot coming from that direction, the angle presented to the line of fire being very acute.

The gun is mounted by trunnions on a compact metal carriage, resting on slides bolted to the sides of the shield. The recoil is received on hydraulic buffers. The amount of recoil allowed for is three feet. The top of the shield, except a space at the breech of the gun, is covered by plating of two inches thickness.

The vertical armor is formed of two thicknesses of steel plating; one enveloping the entire shield is of five inches thickness, and is reinforced at the forward end of the shield, where the angle is greatest, by an inner plating of three inches thickness. The two layers of plating form a shield of eight inches thickness, which at the acute angle presented will be impossible to penetrate with any gun now in use. These shields would be improved by constructing them of taper plates of single thickness, the greatest thickness being placed at the forward part of shield where the angle is greatest; thereby equalizing the resistance of the shield.

The shield and gun are mounted on a deflecting turn-table of eleven feet eight inches diameter, the outer edge of which is shaped like a double convex lens; the office of which is to protect deflectively the conical anti-friction rollers upon which the shield rests. This lens-shaped turn-table is composed of two parts, being divided by a horizontal and a vertical line, as shown by *C* on the cross section drawing, Figure 3.

The lower plate *D* of the deflecting turn-table is secured to the deck of the vessel, and in it are fixed the conical anti-friction rollers upon which the shield rotates. The metal of the lower plate, immediately under the rollers, is cut away, in order to prevent an accumulation of sand or dirt which might clog them. The outer edge of the upper plate *F* embraces the lower plate *D*, thereby giving it a firm lateral support. So that no inordinate strain would be thrown upon the rotating pipe *E* by the rolling of the vessel, or the shield being struck by projectiles.

The lower plate *D* has a circular aperture in the centre through

which rises the rotating and conduit pipe *E* from beneath the curved shield *A*, protecting the water line.

The pipe *E* is secured to the upper plate *F* of the deflecting turn-table, which in turn is secured to, and forms a part of, the bottom of the shield. Consequently when the pipe *E* is turned, the shield and gun, on the deck above, are turned with it.

The shield and gun are trained by a pair of pneumatic engines *G*; pneumatic engines are preferred to steam on account of the exhaust exercising a cooling and ventilating influence. An endless screw on the shaft of the engines engages in a worm wheel secured to the end of the rotating pipe *E*, thereby turning the pipe, shield and gun in either direction with facility.

The pneumatic engines *G* are fitted with link-motion valve gear, with the lever *H* controlling it inside the shield, at the breech of the gun, convenient to the hand of the captain thereof, who trains the gun and shield by the lever without the intervention of any other person.

The lever is so arranged that when it is in the position *a*, the valves of the rotating engines are thrown into position to train the gun and shield in one direction; when in the position *b*, the valves are closed and the shield stationary, and when in the position *c*, the valves will be thrown open to train the gun and shield in the opposite direction.

This training apparatus has great power, there is therefore but little danger of the shield being jammed fast by any obstruction. It will also hold the gun and shield firmly in any desired position, notwithstanding the rolling of the vessel.

Referring to Figure 3, *I* represents a cross section of the pipe by which the shield is trained, which also serves as a conduit for ammunition into the shield. This pipe is V shaped, as shown by the cross section, the object being to present acute deflecting surfaces to projectiles which might strike it. It will be seen that in all positions of the shield and gun the conduit pipe *I* presents a constantly open passage to the magazine, beneath the curved shield, protecting the water line.

The ammunition is passed up through the pipe *I* by means of the traveller *K*, which, in the drawing, shows a cartridge upon it; when it reaches the top of the pipe, inside the shield, it falls over into a little truck *L* ready to receive it. The traveller *K* is actuated by means of the crank *O*. The truck *L* is drawn out to the breech of the gun with the ammunition upon it, traversing the long arm

Fig. 8.

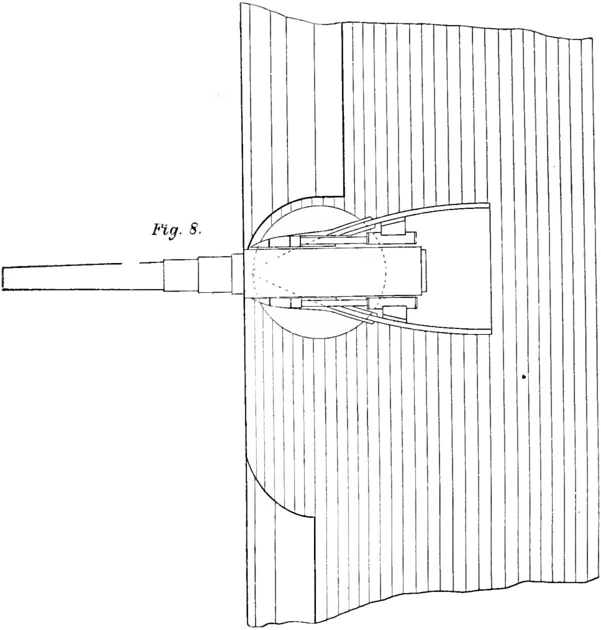
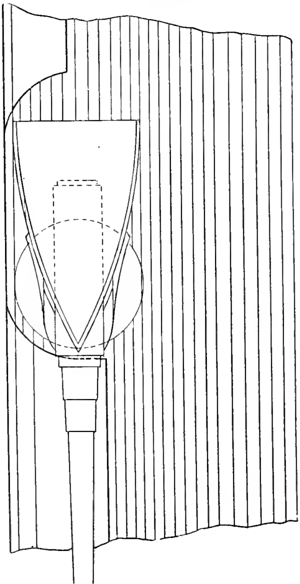


Fig. 9.



of the lever *M*. The long and short arms of this lever are attached to a rock-shaft; the short arm is also attached to the connecting rod of a small hydraulic cylinder *N*, by means of which the ammunition is elevated to the breech of the gun upon the truck at the end of the long arm of the lever, as shown in the drawing. The loading lever *M* when in position to receive ammunition from the conduit pipe is upon the floor of the shield.

The space between the shield and the gun, when the latter is elevated, is kept closed to exclude machine gun missiles, by means of the port stopper *P*, pivoted to the shield directly under the gun, against which it is pressed by means of the spring *Q*, or a counter-weight, thereby closing the space between the shield and gun occasioned by the elevation thereof.

These pivot gun-shields, while in action, should be kept trained so as to deflect projectiles even though the gun be not in use.

There is ample room in the pivot gun-shield for six men, while three men with the special appliances proposed can work the $10\frac{1}{2}''$ gun with facility and efficiency.

The total weight of the pivot gun-shield with the deflecting turn-table, rotating pipe, rotating engines, elevating and loading apparatus, etc., is 65 tons and 20 lbs. But if the shield was made open at the rear it would weigh much less.

The weight could also be greatly decreased by making a shield of less thickness of plating, which would still give a very efficient protection.

The plating of the shield, shown and described, is 8 inches thick, sufficient at the very acute angle presented, if constructed of homogeneous steel, combining hardness with toughness, to deflect projectiles from any gun in existence.

Figure 8 represents a plan view of a vertical V shield of the broadside battery, the gun being trained at right angles to the keel of the vessel. Figure 9 represents a plan view of a similar vertical V shield, open at the rear, in which the gun is represented as being trained parallel with the side of the vessel. The cross sections of these V shields for broadside battery are represented by *RR* in the cross section of the ship, Figure 3. These V shields are mounted in bay-window like projections, which, however, do not extend beyond the line of the ship's side at the water line, the vessel having considerable tumble home.

Broadside guns, mounted in this manner, can be trained so as to deliver fire almost directly ahead or astern.

These small V shields for the broadside guns are trained in the same manner as the large pivot gun-shield, being fitted with the same appliances, and mounted on a deflecting turn-table of similar form, and in addition are pivotted in the *I* beams of the deck above. The guns, however, are not mounted *en barbette*, but extend directly through the shields.

It is proposed to partition off the upper part of the shield by means of a metallic diaphragm, forming a compartment in the upper part for the accommodation of the gun-captain, who is to recline in a prone position; the diaphragm upon which he rests being well padded on each side to deaden concussion. From this position the gun-captain can see through the aperture *S* in the forward end of the shield, and can train his gun by means of the lever, controlling the valve gear of the rotating engines, beneath the curved shield. By the aid of these appliances three men, completely under cover, can load and fire a six-inch rifled gun with far greater rapidity and efficiency than a much larger number of men, exposed upon the open deck, working guns mounted in the ordinary manner.

In view of the great improvements recently made in machine guns of large size, firing percussion shell capable of piercing the sides of unarmored vessels at considerable ranges, it will be seen that a ship having her gun-crews protected in shields of this form will possess an advantage so great that it would doubtless be good policy to have fewer guns, so protected, than a greater number unprotected. In other words, the weight of the battery should be divided between guns and gun-shields, the weight of ammunition remaining the same. The armor of the broadside gun-shields is four inches at the forward end where the angle is greatest, and two inches at the rear end where the angle is very acute.

The weight of the broadside gun-shields of four inches thickness of armor, with the deflecting turn-table, rotating pipe, rotating engines, elevating apparatus, etc., is 10 tons 760 pounds. But such a shield will give an efficient protection against the projectiles of heavy guns, while a shield of but little more than one-third the weight would give protection against machine gun fire, as well as against splinters, fragments of shell, etc., which occasion nine-tenths of the casualties; a small proportion are due to exposure of men in the direct path of large projectiles. The form of the vertical V shields affords protection to the gunners within them against the side splash of splinters and the spread of fragments of exploding shell, thus

Fig. 10.

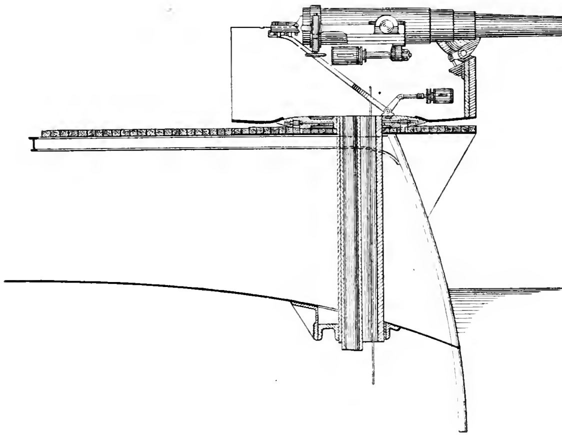
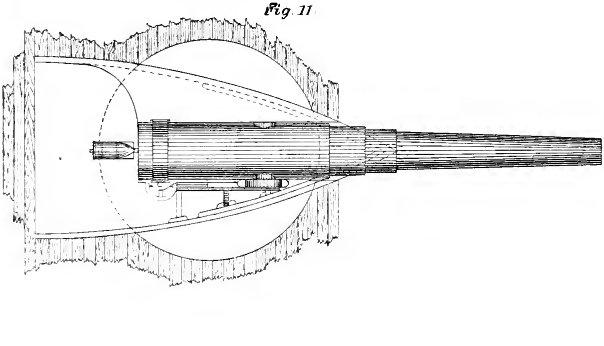


Fig. 11



securing a great advantage over vertical armor, or guns mounted in a large casemate, as splinters and debris could devastate the interior of such a casemate from end to end, while light shields, which would offer no substantial resistance to heavy shot, would afford complete protection against splinters and fragments of shell; the protection obtained in this case against injury from shot by the subdivision of space being analogous to the protection afforded in the direction of buoyancy and stability, by the division of the under-water body into water-tight compartments.

Figure 10 represents a cross section elevation of a vertical V gun-shield, with an 8-inch rifled gun mounted on it *en barbette*. Figure 11 is the plan view of the same. These figures illustrate the proposed method of mounting the pivot guns in the new cruising vessels. This shield is intended to be trained and the gun operated in the same manner as those heretofore described, being fitted with the same appliances; and they permit of the guns being fired either directly ahead or directly astern. As it is open at the rear end, it can be made of a proportionally less weight than the pivot gun-shield heretofore described. The plating is disposed in two layers; the outer one enveloping the entire shield is of three inches thickness, this is reinforced at the forward end, where the angle is greatest, by an inner plating of two inches thickness, making a total thickness of five inches. The best method for the construction of such shields would be by two taper plates.

The weight of this gun-shield with the deflecting turn-table, rotating engines, rotating pipes, loading apparatus, etc., is 32 tons 18 lbs., the weight of the shield itself being 18 tons.

If the deflecting turn-tables, upon which the vertical V shields rest, were supported above the wooden deck on short drums or cylinders of sheet metal a foot or fifteen inches high, which would give an efficient support, while affording no material resistance to shot, being easily penetrable, but very difficult to cut entirely away, the danger of the shield being jammed fast by shot tearing up the wooden deck would be entirely obviated.

The vertical V shields were also recommended for the new ships by the Act of Congress providing for their construction.

In considering the merits of these gun-shields, it should be remembered that the special appliances proposed will enable the guns of a ship to be operated with a much smaller crew; and, if the weight of the extra men required to work the guns by the present system, with

all their belongings, and the provisions and water to sustain them, was credited to the shields, it would balance a large percentage of the weight entailed by them.

It will be seen that the armor of the proposed vessel is to be so arranged as to present no direct resistance to shot, but all the vital and offensive parts are covered by armor which protects deflectively, and the areas of the cross sections of armor are reduced to a minimum in order to present the least possible target to shot.

Projectiles are permitted to pass freely through the vessel, on the principle that the less resistance offered, the less injury received. Shot entering the side of the vessel would plow through the coal or stores packed in compartments above the curved shield, and would be deflected upward, that being the line of the least resistance, and would pass out through the far side of the vessel considerably above the water line.

As the men working the guns are all protected in appropriate deflecting shields, the upward flight of projectiles, after impinging on the curved shield, would not do any serious damage. Even though the upper works of the ship were riddled, she would not be seriously damaged, as her vitals would remain intact.

As the crown of the curved shield rises above the water line, it thereby protects the vital far side of the vessel, where heavy shell would otherwise do the greatest damage by exploding against the frames at, and below, the water line and tearing off entire plates, thereby admitting such great volumes of water as to engulf a vessel at once.

The five vital factors of a war-ship are the water line, the magazine, the motive power, the steering gear, and the personnel. In the proposed vessel, the first four of these and a part of the fifth are protected beneath the curved shield, the remainder of the personnel being protected in the deflecting gun-shields on the decks above.

The curved shield is no more difficult to construct than the plane-sided one, and will cost no more. Nor does it present as much difficulty in construction as the skin plating of an ordinary vessel.

The writer is indebted to Naval Cadet H. G. Leopold, U. S. N., for the diagrams and drawings with which this article is illustrated, as well as for reading it before the meeting of the Institute.

NAVAL INSTITUTE, ANNAPOLIS, MD.

OCTOBER, 1883.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY PROF. CHAS. E. MUNROE, U. S. N. A.

No. V.

It is a well-known fact that the intervention of an obstacle in the path of a beam of sound waves causes the formation of a shadow, but owing to the length of the waves the shadow is not so marked as for light. In 1826, Colladon made experiments which proved that sound shadows are more perfectly defined in water than in air. Prof. John Le Conte has extended these observations, which he publishes in the *Am. Jour. Science* [3], **23**, 27, Jan. 1882, under the title "On Sound Shadows in Water."

The experiments were executed in 1874, during the engineering operations incident to the removal of "Rincon Rock," a sandstone reef in the harbor of San Francisco, by means of "surface blasting" with "giant powder" or dynamite. The depth of water on the reef was about fifteen feet at low tide, with an extreme tidal range of about six feet. The "cans" or "cartridges" of "giant powder" used contained each about fifteen pounds of the explosive compound, comprising about seventy-five per cent. of nitro-glycerine.

It was observed that the suddenness of the shock imparted to the water by this explosive agent produced the most remarkable and astonishing effects. At the distance of 300 feet or more from the detonating cartridge, two distinct shocks were experienced. The first shock came through the intervening waters, and was felt as a short concussion or click before there was any sensible elevation of the

* As it is proposed to continue these notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars.

column of water resting over the point of explosion. The second shock came a little later by the air and was heard. It was evidently communicated to the air by the water, at the time the elastic pulse transmitted by this liquid (the first shock) emerged, in a direction nearly normal to its surface, over a limited area around a point vertically above the exploding cartridge. This was obvious from the fact that aerial sound came from this region. The area, which was the source of the sound transmitted by the air, was the same as that from which the small jets of water (noticed hereafter) were projected. The gases generated during the explosion came to the surface much later than this shock, and after elevating the column of water, over the position of the cartridge, to the height of twenty-five or thirty feet. It is the character of the first shock that deserves special notice. To a person sitting in a small boat floating on the water at a distance of 300 feet or more from the point of explosion, with his feet resting on its bottom, the shock was felt as a sudden blow applied to the soles of the feet. In fact, it drove out the oakum from the seams in the bottom of the boat. When the observer stood on the top of a vertical wooden pile, this shock was felt as a concussion coming up from the water along the cylinder of wood. The concussion produced by such an explosion was so violent that it killed or stunned the fish in the water within a radius of 200 or 300 feet from the explosive centre. They rose to the surface in a helpless condition, and were easily secured.

In these experiments the observer stood on the top of a vertical, cylindrical pile (the trunk of an Oregon pine) about one foot in diameter, situated about forty feet horizontally from the explosive cartridge. A bottle being secured to a rigid rod, was first plunged under the water from ten to twelve inches behind the pile, that is, within its geometrical shadow. The shock of the explosion did not injure the bottle. It was then plunged into the water in front of the pile, or outside its geometrical shadow. In this position the bottle was shivered to atoms by the concussion due to the explosion. The experiments were varied by plunging bottles into the water in various positions around the pile within and outside of its geometrical projections from the explosive centre; and in all cases they were protected from injury when within the geometrical shadow, and were shivered when outside of the same. The same results took place whether the bottles were filled with water or with air. The breaking of a glass vessel by a sudden shock communicated by means of water is a fact

long known, and is illustrated by the old familiar class experiment of exploding a "Prince Rupert drop" while its bulb is plunged into an ordinary phial filled with water.

Cylindrical glass tubes about six feet long and one-fifth inch in diameter, the glass being about 0.5 of an inch in thickness, were also employed. They were covered by pasting cartridge paper over them, so as to prevent the loss of fragments when breakage occurred. The tubes were adjusted to a framework of wood, so arranged that they could be plunged in a horizontal position beneath the surface of the water behind the pile, the axis of the tube being at right angles to the plane of its shadow, and held there (the observer standing as before on the top) with the middle of the tube in the geometrical shadow, while the extremities projected on either side about 2.5 feet beyond the boundaries of said shadow. In every case the shock of the explosion shivered the projecting portions of the tube, and left the portion within the shadow uninjured. The boundaries between the broken and the protected portions of the glass were sharply defined. By standing on the top of a second pile in the direction of the axis of the shadow of the first pile, and distant about 12 feet, the experiments were varied by plunging the framework and tubes—adjusted at right angles to the plane of the prolonged shadow—into the water at this distance (12 feet) from the obstacle which obstructed the sound-wave transmitted by the liquid. The shock of the explosion produced sensibly the same results as when the tube was near to the obstructing obstacle: the protected portion of the horizontal glass tube was sensibly equal in length to the diameter of the pile casting the shadow. Hence the shadow of the cylindrical pile extended back for about 12 feet between sensibly parallel vertical planes, and its boundaries at this distance were still sharply defined. It is evident that, if the explosive centre were of insensible magnitude, the horizontal thickness of the geometrical shadow of the pile, at a distance of twelve feet beyond it, would be augmented in the ratio of 40 to 40 + 12, or of 40 to 52, these numbers being the distances in feet from the centre. So that if the thickness of the shadow at the pile were 12 inches, its thickness at 12 feet beyond would be 15.6 inches. If, however, the explosive energy occupied more or less space (as was the case in relation to the "giant powder" cartridges), the thickness of the geometrical shadow or umbra cast by the pile might not increase sensibly with augmenting distance, and, indeed, in case the exploding body exceeded 12 inches in diameter the thick-

ness of the shadow would diminish with increasing distance from the obstructing pile; as in the case of the umbra cast by an opaque body which is smaller than the luminous source. Another interesting phenomenon came under notice during the execution of these experiments. It was the singular effects observed on the surface of the water (when perfectly calm and glassy) for a certain area around the point immediately over the exploding cartridge. Simultaneous with the first shock transmitted by the water—and before the ascending gases of explosion disturbed it—the surface of the liquid exhibited numerous jets of water, rising to the height of about 3 inches over the centre of the area, and diminishing in height with augmenting distance from the centre. The appearance presented was not unlike that produced by a heavy shower of rain falling on the calm waters of a lake. To an observer in a boat floating on the adjacent water, and consequently viewing the phenomenon from a point near the water-level, there seemed to be a curious quincunx-like arrangement of the jets.

In the case of solitary waves generated by sudden blows and explosions, it is more difficult to form a just estimate of the wave-length than in the case of musical sounds. Nevertheless it is evident that the wave-length must be directly proportional to the time occupied by the displacing impulse multiplied by the velocity of transmission of the elastic pulse. If $L =$ wave-length, $t =$ time of the generating impulse, and $v =$ velocity of sound in the elastic medium, we have L varies as $t \times v$ or $L = t \times v$. Consequently, in a given medium in which v remains constant, L will be a function of t, or the duration of the generative impulse; so that when the factor t is indefinitely small, the value L will be correspondingly small. Hence, when the time of the blow or explosive impulse is exceedingly brief, the wave-length must be proportionately short.

All the phenomena incident to the explosion or detonation of the nitro-glycerine compounds indicate that the impulse generated is of indefinitely brief duration; indeed, its suddenness is almost beyond conception. The efficiency of surface blasting under water by means of these explosive compounds depends upon this extraordinary suddenness of detonation, which renders the effect akin to that of the sudden blow of an enormous unyielding mass. It is evident that the wave generated in an elastic medium like water by an explosion of this character must be very intense and very short. Hence the acoustical shadow produced by an obstacle placed in its path of propagation must,

as in the case of light, be sharply defined and definite in its boundaries. Thus, the striking fact that the protecting influence of the piles on the glass vessels plunged in the water was narrowly circumscribed within the limits of the geometrical shadow may be rationally traced to the extreme shortness of the elastic waves, due to the inconceivably brief duration of action of the generative detonations. If the foregoing is the true explanation of the definiteness of the sound shadows cast in the preceding experiments, then the waves generated by the explosion of ordinary gunpowder, being less sudden, should not produce as sharply defined shadows as those due to the detonation of dynamite. We have, so far as known, no specific experiments testing this point, but it seems to be quite reasonable that such will be found to be the case whenever the test of experiment is applied. For it is well known that the subaqueous explosion of ordinary powder does not give rise to the remarkable concussions so characteristic of the detonations of the nitro-glycerine mixtures. Moreover, if this explanation is correct, the acoustical shadows produced by nitro-glycerine detonations in air ought also to be more sharply defined than those due to sounds less suddenly generated. In other words, if the distinctness of sound shadows depends upon the duration of the impulse which produces the accompanying sound wave, then the definiteness of the shadows cast by sounds propagated through the air should vary with the suddenness of the action of the generating cause.

Inasmuch as the variations in the duration of the genesis of audible sounds in the atmosphere must in ordinary experience be very great, it may at first sight appear incredible that the corresponding differences in the perfection of sound shadows cast by obstacles in the paths of different kinds of sounds should have escaped the most casual observation. But it must be recollected that, for the reasons already assigned, aerial acoustical shadows are not readily appreciated by the ear. Moreover, in the case of sounds transmitted by the air, the distinctness of such shadows is most seriously impaired by the numerous reflected waves which come from circumjacent objects. It should be borne in mind that it is only very recently that the influence of acuteness of sounds on the distinctness of the resulting shadows has been very satisfactorily verified by experiment. In like manner, I venture to predict that careful experiments will verify the deduction that the shadows due to sounds generated by the extraordinarily brief detonations of dynamite are more sharply defined than those

owing their origin to sounds less suddenly produced. In confirmation of the foregoing view the following observation may be cited: On the 16th of April, 1880, an explosion of about 2000 or 3000 pounds of a nitro-glycerine compound occurred at the "Giant Powder Works," situated under a bluff on the eastern shore of the bay of San Francisco, at a distance (determined by triangulation) of 16,201 feet (4938 meters) in a direct line in a northwest direction from my room in the University building. About twenty-five men were blown to atoms; no one escaping to reveal the cause of the accident. The concussion at the University buildings (more than three miles distant) was sufficient to break about a dozen panes of stout glass on the side next to the explosive centre. Nearly every person about the University grounds experienced two distinct shocks; one transmitted by the air, and the other by the ground. The cottage occupied by my brother was situated in the geometrical shadow of one of the buildings; being about 890 feet on the farther side of it. No aerial shock was experienced by him or any member of the household; and the concussion transmitted by the earth was alone felt as a shock emanating from the floor. In other terms, the acoustical shadows cast by the intervening structure completely cut off the sound-wave coming by the air. It is scarcely necessary to add that for ordinary sounds such would not have been the result. The singular phenomenon observed of numerous small jets projected from the surface of the water when the shock transmitted by the liquid reached the surface area above the exploded cartridge, was probably due to the circumstance that when the short and intense electric wave emerged in a direction normal, or nearly normal, to the aqueous surface, the tense superficial capillary film yielded to the sudden impulse more readily at some points than others. The sensibly homogeneous character of such a tensile elastic film would naturally tend to group the points of rupture, or jets of water, into more or less perfect order, partaking more or less of geometrical symmetry. Hence the curious quincunx-like arrangement of jets as viewed by the observer near the water-level. According to this view the phenomenon in question seems to find its counterpart or analogue in the more or less symmetrical forms produced by the intersection of the lines of rupture, as the result of tensional strains due to the contraction of homogeneous masses during the process of cooling or of desiccation.

Thus the columnar structure of certain igneous rocks seems to be due to the tensile stress of contractions by cooling after solidification

supervened; while the analogous structure developed by the desiccation of homogeneous masses of moist clay, mud or starch, appears to be produced by a similar strain consequent upon shrinkage from loss of moisture. In a similar manner the tense superficial capillary film of the water when it experiences the sudden molecular impulse due to the emergence of the elastic pulse, is ruptured along lines more or less symmetrically disposed on the surface of the water; and the liquid beneath is projected through these lines or points of least resistance.

In connection with the foregoing the observations of Gen. Abbot (*Report on Submarine Mines*, p. 41) may prove interesting. Thus he states that:

"Before proceeding to discuss mathematically the action of the forces developed by explosions under water, a brief abstract will be given of notes relating to what is usually heard, felt and seen in the vicinity. The sound is deadened to a surprising degree by water over the charge. A large torpedo exploded 10 feet or more below the surface gives a dull muffled report that often is hardly noticed by one intently watching the jet. When the water covering is so thin as to allow the gas instantly to escape into the air, the sound is far more intense. Thus one pound of dynamite exploded three feet below the surface produces locally a much louder sound than 500 pounds submerged 20 feet. It is a general characteristic of small and deeply submerged charges of the explosive compounds, and of some quick acting explosive mixtures as well, that at the instant of detonation, before any disturbance of the water at the surface is visible, three sharp sounds are heard resembling raps upon a hard substance. They are of nearly equal intensity; but the interval of time between the first and the second appears to be longer than between the second and the third. That these repetitions are not simply echoes, and that there are really more than three of the impulses, although the ear hardly detects a greater number, have been conclusively proved in several instances where a gauge clutch happened to be out of order. In such cases several successive indentations in the bottom of the lead have been made by the centre pin as the cylinder moved laterally under the upward jerk given by the buoy. Successive impulses may also be distinctly felt by one standing in a boat near the explosion; and if the hand be placed in the water, sensations resembling electric shocks are experienced. The influence of the shock upon fish is

noteworthy. In the immediate vicinity, even of small charges, death appears to be instantaneous. At a greater distance the air bladder is ruptured, and the air ballast escaping into the abdomen, the fish floats upon its back at the surface, although still able to swim with considerable speed. At still longer ranges the effect appears to be momentary, simply causing an upward dart into the air. Even five pounds of dynamite will produce this effect upon a shoal of menhaden at distances of several hundred yards, showing that the nervous system of that fish is one of the most sensitive of known gauges.

The jet, as well as the sound, is greatly influenced by the submergence. As small charges afford the best opportunity for studying this phenomenon in detail, the following summary of many records upon explosive compounds is given. A charge of one-fourth of a pound submerged about 35 feet occasions no marked disturbance at the surface, but bubbles of gas continue to rise for many seconds. Fish at 100 yards distance often leap into the air. A half-pound charge detonated 6 feet below the surface produces a sharp report, and throws up a jet from 20 to 30 feet into the air. With a one pound charge submerged 35 feet, the buoy supporting the ring instantly rises about 2 feet and sinks back out of sight. An upward, boiling motion of the water begins about 12 seconds after the explosion. In a strong current this may appear several feet away from the buoy. When the charge is submerged 25 feet the boil rises quicker, and the buoy often re-appears with it. With a two pound charge submerged 35 feet the phenomena are similar, the boil appearing in about 9 seconds. With a 3 pound charge at the same depth the upward current of water assumes the appearance of a small dome at the surface, appearing about 5 seconds after the explosion. The buoy rises 4 or 5 feet instantly, and sinks back out of sight. As the charge is increased to 5, 8 and 10 pounds, the depth remaining the same, the greater intensity of action is shown by a quicker motion of the buoy, which is also surrounded by a mist thrown upward from the surface. The dome appears in a second or two, and expands into a small white jet of water 8 or 10 feet high. A boat 50 feet distant from the buoy receives a jar sufficient to lift small articles. Fishes of the herring family dart into the air as far off as the eye can conveniently distinguish them, those within a radius of a couple of hundred feet being crippled by the concussion. With explosive mixtures the effects are similar but less intense. For example, 25 pounds of mortar powder, fired 35 feet below the surface, cause a misty shower to rise

a foot or two above the water; the buoy shoots up to its full length and falls upon its side; then a white dome rises around it about 10 feet high. When a strong iron case is used, three sharp raps are heard, which are not often noticed with a wooden case. When 50 pounds of mortar powder are fired 5 feet below the surface, the jet is about 170 feet high; at 16 feet it is about 40 feet high; at 35 feet it is 20 to 30 feet high; and at 68 feet there is simply a large upward boil around the buoy, occurring several seconds after the explosion. In deep explosions the buoy always shoots upward, and often subsides before any disturbance is seen at the surface.

The *Bulletins de l'Académie Royale de Belgique* contain an extract of a work upon *experimental ballistics*, by M. Melsens, in which the learned writer propounds a remarkable theory in regard to the action of the air existing in front of projectiles, and which forms one with the solid projectile during the greater part of its course.

M. Melsens describes one of the various contrivances he made use of for receiving the air in front of a projectile moving at a great speed; it consists practically in firing a bullet in a trunconical aperture made in a solid block of steel or cast-iron; at the extreme end of the cone, towards the summit, the aperture of the cone may be several millimetres in diameter; it is made to communicate with iron tubes previously filled with water, which extend into a pneumatic trough containing a bell for the reception of the air.

When a spherical leaden ball enters the cone, which is constructed so as to prevent the outflow of the water, the air in front of it is driven forward; a portion of the ball enters the orifice of the cone, and the remainder, being wedged in it, forms an obstruction and prevents the escape of the water. The part in the cone often terminates in a perfect point, very sharp and tapering; sometimes a characteristic stricture is observed which recalls what has been named in liquids *the contraction of the vein*. Bullets are seen in which this bulging out forward is ready to separate. Detached and isolated drops are found in the tube, as if the solid lead had flowed like a liquid.

M. Melsens' experiments differ from those of M. Tresca, in the fact that while in the former we find drops that are entirely free and every stage of whose formations we can to a certain extent follow, in the latter the flowing of the solid lead, under high pressure, causes the converging motions of the molecules pressing on all sides towards the orifice to yield to the pressures which, spreading from the upper part

of the block, extend throughout the whole mass, determining what in liquids has been termed the contraction of the vein.

Upon the subject of the resistance of air in gun-barrels, Prof. Colladon has addressed to M. Melsens a letter containing some curious and little-known facts, which we think useful to reproduce *in extenso :*

My honored colleague : Your work on experimental ballistics, and the interesting phenomena which you have discovered and described in the paper you sent me, determined me to communicate to you an old experiment which I have often repeated, either before my scholars at the *Ecole Centrale des Arts et Manufactures*, in Paris, or later, during my course of instruction in the scientific branch, at the Academy of Geneva.

The Swiss carbines used in target practice about 60 years ago were pretty heavy pieces; the barrels, generally very thick, were longer than those of modern rifles; besides, at that time, they used spherical balls. There are examples of target-shooters who, on a wager, loaded their carbine with a round ball, grasped firmly the extremity of the barrel, closed the muzzle with their thumb, and fired their piece without the thumb being injured, which presupposes a rare strength in the wrist and muscles.

Having been intrusted with the instruction in theoretical and applied mechanics, at the *Ecole Centrale des Arts et Manufactures de Paris*, in 1830, shortly after the formation of that Institution, I introduced in the course of my lectures a great many new experiments, and set in motion before my scholars apparatus or pieces of machinery borrowed from private parties. Among other experiments, I used to repeat every year, as I did later, at the Academy of Geneva, an experiment recalling that which I communicated to you.

I loaded heavily, by means of compressed air, the hollow iron breech of an air-gun, then screwing down the barrel, I introduced in it a round leaden ball, moving freely, but with a diameter very little less than that of the bore of the gun. Placing then the air-gun in an upright position, with the stock resting on the floor, I grasped firmly the extremity of the barrel, and pressing tightly my thumb over the muzzle, I ordered my assistant to pull the trigger; my thumb remained undisturbed and the ball was heard falling back in the barrel. After this, without any additional charge and with the same ball, in the presence of the audience, I fired at a deal-board from one to one-and-a-half centimetre thick, and the plank was pierced through;

generally my assistant, who had implicit trust in my aim, held in his hand the small board, or a piece of glass in which the bullet made a pretty clear hole with but very few cracks.

The experiment, I repeat, is without any danger to the operator, if he can trust to his muscles, if the barrel is more than 80 centimetres long, if the ball is spherical, and if its diameter differs very little from that of the bore, for this ball must act as a piston, and its whole energy must be exclusively employed in compressing the air whose egress is prevented by the thumb.

I presume it would be dangerous to load the gun with a bullet of too small a diameter, or with small shot. It is hardly necessary to add that the least instability in the vigorous pressure of the thumb, or in the impervious closing of the bore, would cause the bullet to hit and probably to seriously hurt the extremity of the thumb; it also seems to me that a conical bullet would prove more dangerous than a spherical one, for, according to the power of the charge and the length of the barrel, the bullet must come very close to the thumb before its energy is spent in the act of compression. At any rate, we would dread the burning of the skin of that part of the thumb closing the orifice, for this is an experiment in every way analogous to that of the pneumatic tinder-box, when compressed with great force; doubtless, the time is too short for any serious harm being done. I have repeated the experiment more than a score of times without any injury, either from shock or heat.

DANIEL COLLADON.

GENEVA, *May* 31, 1882.

M. Melsens, in publishing this letter, says, that on communicating the very curious facts contained in it to several artillery officers, otherwise very learned and quite familiar with subjects on ballistics, they professed entire ignorance of them. (*Mem. Soc. Ing. Civ.*, p. 190, August, 1882.)

Several rifle barrels having been swollen and burst, a board of officers were appointed, June 12, 1882, to report upon them, and especially as to the cause of their being swollen at the muzzle. On meeting at Springfield, Mass., the board proceeded to examine the records of the post, and also considered the results of experiments made by direction of the commanding officer.

They find that in September, 1879 (*Ordnance Notes*, No. 117), the

following experiments were made by Captain Greer, Ordnance Department, as indicated by his report as follows: "Two condemned barrels were taken at random from a lot turned in from the field. Eight or ten rounds were fired from each of them, rags of various sizes having been inserted in the bore, a little below the front sight, without affecting the barrel the slightest. Sand next having been inserted in the muzzle, the barrel was shaken so as to remove all but a few grains which adhered to the fouling; the piece was then fired. This was repeated several times without swelling the muzzle. The barrel was then run into wet sand, and the bore nearly filled for about an inch and a half. After firing in this condition the barrel was found swelled at the muzzle precisely like those that have been received from time to time from the field. Several pine plugs from six to eight inches in length were then prepared of a size to fit the bore closely. The second barrel was fired twice with the plugs driven in dry, about one-half their length, twice driven in wet, and twice driven in dry but afterwards swelled by steam, both inside and outside, without injury to the barrel. The inclosed air probably forced the plugs out before the bullets reached them. A plug was then split in two to represent a broken tompion, the air being free to pass by the plug. It was thought the bullet might wedge on the remaining side of the plug, but the barrel was found uninjured after the shot was fired. Occasionally a cup anvil of the Frankford service shell has been found in the barrel after firing. It was thought possible that one of these might become wedged in the barrel and cause the swelling. To test this question an anvil was driven down squarely across the barrel just opposite the front sight. The piece was then fired without injury to the barrel. A second anvil was driven down to the same position, but obliquely to the axis of the bore. No damage resulted from the firing. A long wad of cotton waste was then wet and rolled into a spiral and forced down the barrel several inches by the ramrod. The piece was then fired, when the barrel was found swelled a little beyond the wad, which was probably carried forward a few inches before the bullet wedged upon it." Recently the following experiments were made by direction of Colonel Buffington. A barrel received from the field with a swollen muzzle was cut off back of the swell. The muzzle was then pushed into wet sand and the gun discharged, using the service cartridge, resulting in a swollen muzzle. A second similar gun barrel was taken, the swollen muzzle cut off, the gun fired, the end thrust into dry sand and fired

again, with no perceptible swelling; it was then fired twice more with the consequent increase of fouling, the muzzle end rested in dry sand just as might easily happen at target practice from carelessness; then it was fired again and the muzzle found to be swollen. From these experiments it is evident that an obstruction in the bore, particularly sand, will cause a swelling of the barrel. That men frequently lay their guns down or stand with the muzzle resting in the sand no one will probably deny. Such action is liable to pick up sand in the muzzle, particularly after the gun has been fired, resulting in swelling the barrel after firing again. The swelling never takes place from firing a service cartridge when there is no obstruction in the bore. (*Ordnance Notes, U. S. A.*, No. 238.)

The new six-inch breech-loading steel rifle has recently been tried by Lieutenant-Commander Folger, U. S. N., at the Naval Experimental Battery; and with a charge of 32 pounds, and a projectile weighing 68 pounds, a muzzle velocity of 2130 feet per second was obtained, while the pressure was but 30,720 pounds per sq. inch. Considering the conditions of chamber-space (920 cub. inch), length of bore and weight of projectile, the results are unsurpassed by any hitherto obtained abroad. (*Science*, **1**, 291, April 13, 1883.)

The *Revue Scientifique*, **28**, 769, December 17, 1882; **29**, 75, January 21, 1882, and 109, January 28, 1882, contains an exceedingly important article by Berthelot, on "Explosives," in which he reviews the work recently done, and states his present belief as to the cause and character of explosive phenomena and the properties of explosive substances. In the discussion of explosions by influence, he takes exception to the theory of *synchronous vibrations* proposed by Abel* and apparently supported by the experiments of Champion and Peliet, and offers a new theory of his own, which we shall treat of at length later. His method of accounting for the change brought about in the explosive power of gum dynamite, gun cotton and the like, by admixture of inert substances, is interesting. He holds that the camphor modifies the cohesion of the mass of the substance. The substance thus acquires a certain elasticity and solidity, in consequence of which the initial shock of a detonator propagates itself at the start through a much greater mass of the substance than it would if the camphor were not present. A portion of the energy

* Proc. Nav. Inst. **4**, 31.

is expended in rending the mass, while some of it is converted into heat; but this heat is dispersed through a greater mass, hence a sudden and local elevation of temperature capable of inducing chemical and mechanical action, cannot be produced but with difficulty, and hence a greater weight of the detonating substance is required where camphor is present. Camphor, however, according to the theory, does not exert any influence on discontinuous powders, and this is shown in practice with potassium chlorate powders. This theory of discontinuity is also illustrated by the statement "that frozen dynamite jelly possesses a sensibility to shock comparable to that of nitro-glycerine if the solidity of the parts has become destroyed by crystallization."

This work of Berthelot's has been translated by M. Benjamin, and published in *Van Nostrand's Engineering Magazine*, **29**, 100, August, 1883, but it is rarely that we have met with such wretched, slovenly and unreliable literary work, and it is an added injustice to the eminent author that no reference is made to the source from which the original is drawn. It is only justice to the translator to say, that as he had no opportuntiy for revising the proof-sheets he cannot be held responsible for the condition of his article. As this is a work with which all students of explosives must become familiar, and as few of them may meet with it in the original, they will be pleased to hear that the article is to be revised and published in a permanent and convenient form, together with a Bibliography of Explosives, in *Van Nostrand's Science Series.*

The same number of *Van Nostrand's Engineering*, p. 125, contains a bright and entertaining article entitled "Who Discovered Gunpowder?" being a translation by Lieutenant John P. Wisser, from the German of Karl Braun, *Nord und Süd*, June, 1883. The article goes to show that the knowledge of gunpowder was brought to Augsburg in 1353 by a Jew named Typsiles, and that from Augsburg, the preparation of gunpowder, its application to military purposes, and the manufacture of firearms, spread throughout Germany and over the rest of Europe. It is conjectured that this Typsiles came from the Orient, and brought thence a knowledge of Greek fire into the free imperial city of Augsburg. Thus is the story of Berthold Schwarz, the Freiburg monk, relegated to the realm of fiction.

In the *Précis and Translations of the Royal Artil. Inst.*, April, '83, is a translation by Captain J. C. Dalton, R. A., from *Memorial*

d'Artillêria, April, '82, on the Portuguese army, from which we learn that the powder factory is at Barcasena, 8¾ miles from Lisbon, where the powder is made for the old guns; that for the Krupp guns is procured in Germany. The different classes of powder made at Barcasena have the following compositions:

Class of Powder.	Mark.	Composition. Saltpetre.	Sulphur.	Charcoal.
Mining powder,	MM	62	18	20
Gunpowder, fine grain,	P. F.	76	10	14
" No. 1, extra fine,	P. S. F. N. 1	76	10	14
" No. 2,	P. S. F. N. 2	76	10	14
" large grain,	S	75	12.5	12.5
" small grain,	FF	75	12.5	12.5
" rifle,	FN	76	10	14
" shell,	FNC	76	10	14

They have also tried a powder to take the place of the German powder, and in the experiments made with the 9 cm. gun they obtained with the 33 lb. charge of the same powder an initial velocity of 1512 f. s. The Laboratory is at Braço de Rata, 4½ miles from Lisbon.

H. Güttler proposes to make cartridges of compressed blasting powder by cementing the grains together with dextrine. For this purpose he uses a brown-red charcoal made from resin-free wood at a temperature of 270°–310° C. and which he claims has the formula $C_8H_4O_2$. The mixture of charcoal, sulphur and nitre is incorporated with the solution of dextrine, corned in grains of 1–2 mm. and after drying pressed into perforated cylinders. These cylinders are dried and shellacked. The reaction on explosion is represented by the equation

$$C_8H_4O_2 + 8KNO_3 + 4S = 8CO_2 + 2H_2O + 8N + 2K_2SO_4 + 2K_2S$$

when potash nitre is used. When soda nitre is employed the reaction is similar, but Na takes the place of K. (*Chemisch-technisches Repertorium*, p. 154, 1883.)

The output of the Spanish Powder Mill at Murcia* for the year 1880–1881 was 102,860 kilos of powder. Of this 16,084 kilos were prismatic powder with seven canals.† While this was as good as the

* Proc. Nav. Inst. **8**, 673. † *Ibid.* **8**, 463.

English or German powders, it was much cheaper, since it cost but from forty-eight to fifty cents per kilo. (*Mitt. Artill. u. Genie- Wesens*, 1883. *Kleine Notz*, 19.)

Under the title " Lecture Experiments with Zinc-dust and Sulphur," H. Schwarz calls attention to the vigorous action which attends their union. Ordinarily a mixture of fine iron or fine copper and sulphur is used for showing the phenomena attending chemical union. Schwarz tried zinc-dust and sulphur, and to his surprise his crucible blew up. Experimenting further, he found that a mixture of the substances in atomic proportions is the most useful. This he obtains by passing a mixture of two parts of zinc and one part of sulphur through a sieve. This may be readily ignited by a match, when it burns like gunpowder, with a vivid, brilliant flame, somewhat greenish in color, and leaving only a slight yellowish-white residue of zinc sulphide. It may also be exploded by the blow of a hammer. When tried in a small testing-mortar, two grams of the zinc and sulphur mixture were found to produce the same effect as one-half a gram of gunpowder. (*Ber. Berl. Chem. Ges.* **15**, 15, 2505, Nov. 13, 1882.)

Prof. C. L. Bloxam publishes an article under the title " Reconversion of Nitro-Glycerine into Glycerine," *Chem. News*, **47**, 169, April 13, 1883. He states that the following experiments on this subject appear to possess some interest at the present moment:

1. Nitro-glycerine was shaken with methylated alcohol, which dissolves it readily, and the solution was mixed with an alcoholic solution of KHS (prepared by dissolving KHO in methylated spirit and saturating with H_2S gas). Considerable rise of temperature took place, the liquid became red, a large quantity of sulphur separated, and the nitro-glycerine was entirely decomposed.

2. Nitro-glycerine was shaken with a strong aqueous solution of commercial K_2S. The same changes were observed as in 1, but the rise in temperature was not so great, and the liquid became opaque very suddenly when the decomposition of the nitro-glycerine was completed.

3. The ordinary yellow solution of ammonium sulphide used in the laboratory had the same effect as the K_2S. In this case the mixture was evaporated to dryness on the steam-bath, when bubbles of gas were evolved, due to the decomposition of the ammonium nitrite. The pasty mass of sulphur was treated with alcohol, which extracted the glycerine, subsequently recovered by evaporation. Another por-

tion of the mixture of nitro-glycerine with ammonium sulphide was treated with excess of $PbCO_3$ and a little lead acetate, filtered, and the ammonium nitrite detected in the solution. The qualitative results would be expressed by the equation $C_3H_5(NO_3)_3 + 3NH_4HS = C_3H_5(OH)_3 + 3NH_4NO_2 + S_3$, which is similar to that for the action of potassium hydrosulphide upon gun-cotton.

4. Flowers of sulphur and slaked lime were boiled with water till a bright orange solution was obtained. This was filtered, and some nitro-glycerine poured into it. The reduction took place much more slowly than in the other cases, and more agitation was required, because the nitro-glycerine became coated with sulphur. In a few minutes, the reduction appearing to be complete, the separated sulphur was filtered off; the filtrate was clear, and the sulphur bore hammering without the slightest indication of nitro-glycerine.

This would be the cheapest method of decomposing nitro-glycerine. Perhaps the calcium sulphide of tank-waste, obtainable from the alkali works, might answer the purpose.

The reducing action of alkaline sulphides on nitro-glycerine has been pointed out some time since,* and its quantitative application is previously mentioned in these notes.†

On page 448, Vol. VIII, an account is given of the experiments of Mr. Volney and Dr. Henry Morton on the separation of nitro-glycerine from nitrosaccharose. Mr. R. S. Penniman, of the Atlantic Dynamite Works, writes that "as I first suggested and performed the experiment described in 'Notes' No. 2, for the separation of nitro-glycerine from nitro-sugar by the distillation of the nitro-glycerine, I may be permitted to state that this method is not absolutely accurate in its determination of amount of nitro-sugar present, for the reason that the nitro-sugar is also slowly volatile at this temperature, 250° F., and some is driven off with the nitro-glycerine."

S. H. Hinde proposes a new explosive mixture composed of 64 parts of nitro-glycerine, 12 of ammonium citrate, 0.25 of ethyl palmitate, 0.25 of calcium carbonate, 23 of coal and 0.50 of sodium carbonate. (*Chemisch-technisches Repertorium*, p. 153, 1883.)

"Pyronome" is the name given to a new explosive mixture by M. Sandoy, consisting of 69 parts of saltpetre, 9 of sulphur, 10 of

* Mowbray, 3d Ed., 1874, p. 58. W. N. Hill, Rept. Secy. Navy, 1876, p. 168.
† Nav. Inst. Proc. **9**, 294.

charcoal, 8 of metallic antimony, 5 of potassium chlorate, 4 of rye flour and a few centigrams of potassium chromate. These are to be mixed in an equal volume of boiling water and the mass evaporated down to a paste, dried and powdered as wanted. This mixture is said to be cheaper than dynamite, but its manufacture and use must be attended with considerable danger. (*Chem.-tech. Repertorium*, p. 154, 1883. *Boston Journal of Chemistry*, **16**, 16, Feb. 1882.)

B. G. & F. L. Benedict have proposed the following mixture for use in primers to replace fulminating mercury: Amorphous phosphorus, 2 parts; minium, 8 parts; potassium chlorate, 2 parts. The oxides of mercury or manganese may be used in the place of the minium. (*Chemisch-technisches Repertorium*, p. 153, 1883.) This differs but little from the caps which caused the explosion in the Rue Beranger, Paris, May 14, 1878. Of these the kind called "single" consisted of

Potassium chlorate,	12	parts.
Amorphous phosphorus,	6	"
Lead oxide,	12	"
Resin,	1	"

while the "double" were composed of

Potassium chlorate,	9	parts.
Amorphous phosphorus,	1	"
Antimony sulphide,	1	"
Sulphur, sublimed,	0.25	"
Nitre,	0.25	"

(*Revue Scientifique*, **29**, 80, Jan. 21, 80, 1882.)

A new explosive* has just been patented in England by Dr. C. W. Siemens. The compound is a mixture of saltpetre, chlorate of potash and a solid hydrocarbon, and is suitable both for mining purposes and firearms, while, if ignited in the open air, the combustion takes place slowly and imperfectly, and therefore without danger. The incorporation of the ingredients is by preference effected as follows: The saltpetre, chlorate of potash and hydrocarbon (for which may be taken paraffin, asphaltum, pitch, caoutchouc, gutta-percha, etc.) are mixed together in pulverulent form by passing through sieves or otherwise, and the mixture is then treated with a liquid volatile hydro-

* Nav. Inst. Proc. **9**, 298.

carbon, which acts as a solvent to the solid hydrocarbon. A plastic mass is thus produced, which is then formed into cakes or sheets by passing through rollers or otherwise, and is rendered hard by evaporating the liquid solvent used, the sheets or cakes so produced being then converted into grains or pieces of any desired size, in the same manner as ordinary gunpowder. The new compound, which has about the same density as ordinary gunpowder, and is very hard, possesses with equal volume more than double the explosive force of the latter. The intensity of explosion can be regulated at will by varying the proportions of the ingredients and the size of the granules. These proportions should, generally speaking, be such that for each volume of the hydrocarbon, when converted into a gaseous state, there shall be present in the other ingredients three volumes of oxygen. (*Wash. Sunday Herald*, Jan. 14, 1883.)

On page 455, Vol. VIII, Proc. Naval Institute, reference was made to the fact that the British Dynamite Company are now using iron tanks for transportation of their sulphuric acid in the place of the fragile glass carboys formerly used. In a paper on "The Appointment of a U. S. Commission of Tests of Metals," *Trans. Am. Socy. Mechanical Eng.*, 1882, p. 8, Dr. Thomas Egleston points out that instead of the general belief, that the presence of sulphur and phosphorus in iron is always objectionable, being true, it is on the contrary found that for certain uses it is highly desirable, and that among others it has been found that the parting pots used in mints, formerly made of platinum at enormous cost, can be advantageously replaced by iron containing a certain percentage of either phosphorus or silicon, which will resist the action of acids even better than the more expensive metal. And if some means of casting ferro-silicon containing from ten to fifteen per cent. of silicon could be found it would be invaluable, since it has been shown that this substance is completely insoluble in aqua regia.

In connection with the note on page 311, Vol. VIII, the following abstract from the *Danbury* (Ct.) *News*, found in the *Boston Journal* of July 30, 1883, may prove interesting:

"A carboy of nitric acid broke in a car on the New York City and Northern road on its way to Danbury, Sunday evening. On its arrival here at 8 o'clock, a blue flame was seen to issue from its roof by Frank Wheeler, an employe of the New England Company.

Station Agent Pearce was notified, who made an examination and learned the cause of the trouble. He and several others immediately set to work to empty the car, a difficult and dangerous task, as the inside of the car was full of the destroying gas. One of the helpers was Harry N. Baker, in the employ of the New England Company. He went home after the car was cleared and was attacked with nausea. He was at work Monday morning, but shortly was taken ill and returned home, where he now lies in an unconscious state, and with no hope of his recovery. The physicians in charge say his lungs are coated with the poisonous gas."

On page 287, Vol. IX of the Proceedings, a resumé of Abbot's report on Submarine Mines is given. Gen. Abbot has now issued Addendum I to this report, embodying the results obtained with tonite, California gun-cotton and rackarock. The tonite had been manufactured in the United States for about a year by the Tonite Powder Company of San Francisco, under patents assigned by the Cotton Powder Company Limited of London, when in the summer of 1882 samples were procured for trial at Willet's Point. The shipment was made on the Pacific railroad. The works of the company, near Stege station on the Central Pacific, are reported to have a capacity of twenty tons monthly, and it is understood that similar works are to be erected in the East. The standard tonite made by the company consists of 52.5 parts of gun-cotton and 47.5 parts of nitrate of baryta; but for special purposes, and by request, a part of the latter is sometimes replaced by potassium or sodium nitrate.

Two varieties of the standard explosive were received—one dry in compacted cartridges, and the other damp in bulk. The damp as sent contained 18 per cent. of moisture, but when received it held but 13.5 per cent. The uncompressed damp tonite was detonated with dry tonite or gun-cotton. The relative efficiency in a horizontal plane as compared with dynamite No. 1 was found to be 0.81 for the dry compressed state and 0.85 for the other, giving as an average value 0.83. The explosive therefore takes rank just below gun-cotton (0.87). The result is not unlike what might be anticipated from the chemical composition of these two explosives, and it is evident that the substitution of a portion of nitrate of baryta tends rather to reduce than to increase the normal intensity of action of gun-cotton, pound for pound, when fired under water.

The Tonite Powder Company of San Francisco also manufactures

gun-cotton by a process which appears from their circulars to be essentially that of Prof. Abel—omitting the compression into cartridges. It was regarded as desirable to test this product at Willet's Point, in the usual manner, to learn how it compares in strength with that made in England. A sample was accordingly procured with the tonite in the summer of 1882. The explosive was delivered damp in the state of loose powder, which when dry became a fine white dust. The following statement respecting it was received from Mr. W. L. Oliver, general manager of company:

"Lot No. 3.—This is 120 pounds gun-cotton (pulverized) containing 24 per cent. of moisture. This lot of gun-cotton gave by assay 89.60 per cent. insoluble tri-nitro-cellulose and 10.40 per cent. soluble gun-cotton. This is not quite up to our average, which is about 93 per cent., owing to the acid of late being rather inferior; but nevertheless the gun-cotton is good, and is 7 per cent. above the standard required by the British Government. The test for purity and acidity from two samples stood 246° and 250° Fah. for 28 minutes, the British Government standard being 150° for 10; and these samples subjected to a long and steadily increasing temperature stood 358° and 360° before it flashed, and a fresh sample started at 200° stood 364°. Such gun-cotton will keep unaltered for many years in any climate."

This gun-cotton was shipped across the country packed in a barrel. To determine whether, when actually tested, the explosive retained the full 24 per cent. of moisture, a sample of 400 grains was withdrawn from the bottom of the mass and desiccated to dryness. The loss proved to be 80.6 grains or only 20 per cent. These figures were used in estimating the charges in preference to those furnished by the company, because some loss of moisture was to be expected under the circumstances. The firing test showed this gun-cotton to be not inferior in explosive intensity to the best English manufacture, but in the form furnished it was so bulky that very solid packing was necessary to force 4.2 pounds into a No. 2 can, which will readily receive 10 pounds of dynamite in loose powder. This bulk would be a fatal objection for use in ground mines, but would be perhaps an advantage in buoyant torpedoes.

The Rackarock, supplied by the Rendrock Powder Company of New York, was brought to Gen. Abbot's notice in the winter of 1882, by one of the manufacturers. It consists of a solid, composed mainly of potassium chlorate, in fine powder, given a reddish tint by some

coloring matter; and of an oily liquid, having the strong, bitter almond smell characteristic of nitro-benzol. These compounds, neither of which is explosive by itself, are combined before use by immersing the solid in the liquid for a few seconds until an increase in weight of about one-third is effected by absorption. The solid is supplied in the form of loosely packed cartridges of different sizes, put up in bags closed at each end. The combination of the ingredients is effected by means of an open basket of wire to receive the cartridges, which is suspended from a spring balance and dipped in a galvanized iron pail containing the fluid. A little attention to the time of immersion renders the absorption fairly uniform. The explosive, when prepared in this manner, is a compact red solid, having a specific gravity of about 1.7. It decrepitates with difficulty when hammered on an anvil, but hardly ignites on wood. A fuse containing 24 grains of fulminating mercury fails to explode a cartridge unconfined or loosely confined. Even if it be compacted in an auger-hole in a log and tamped with mud the explosion is only partial. A cartridge struck by a bullet from a Springfield rifle flashes but does not detonate. Ordinary friction seems to have little tendency to cause explosion. These facts show it to be quite safe to handle even when ready for use, and it has given excellent results in rock-blasting under General Newton at Flood Rock. Its peculiar chemical composition gives rackarock the interest of novelty among modern high explosives, and it has accordingly been tested with special care to discover the intensity of action of which it is capable when fired under water. Two fluids were supplied for the trials—the usual one consisting essentially of nitro-benzol; and the other, of a special preparation consisting of the same saturated with picric acid (12 to 16 per cent. according to the quality of the solvent). The explosives prepared by absorbing these fluids by the solid are designated as "rackarock" and "rackarock special."

The results of the firing tests showed that rackarock, fired under water, gives a relative efficiency in the horizontal plane of 0.86, being nearly equivalent to gun-cotton, and a study of the results proved that there is no difference in the intensity of action between rackarock and rackarock special, which exceeds the range of variation with either of them, but there was a considerable variation with each of them. That this should be so in a mixture of which the ingredients are combined by the rough method described above is not surprising. Moreover, nitro-benzol itself (formed by treating crude benzene with fuming nitric acid) is certainly subject to important variations in

chemical composition, due to its impurities; and the same is probably true of the solid as supplied in the trade cartridges.

The anomalous variations noted were confined to the firing of two days. It is to be regretted that the causes which produced the excessive pressures could not be detected, for if the peculiar conditions corresponding to the greatest intensities of action could always be fulfilled this explosive would take rank with explosive gelatine itself instead of with gun-cotton for use under water.

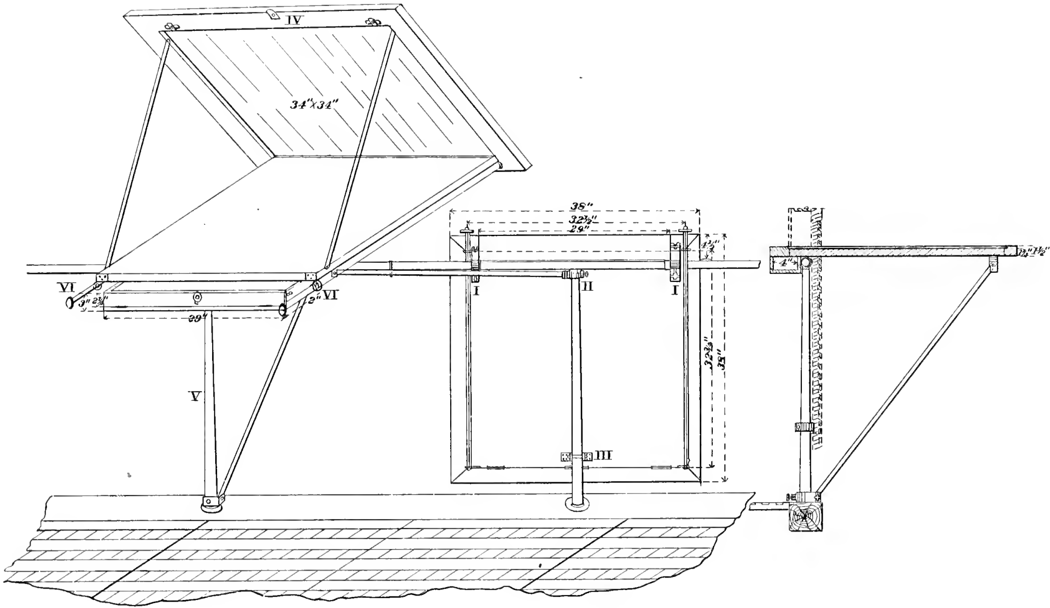
Gen. Abbot concludes that "rackarock possesses the merits of high intensity of action, unusual density, absolute safety in handling and storage (components unmixed) and little cost; on the other hand, under the conditions of my tests, an exceptionally strong detonating primer is essential to develop its full power. Experiment alone can determine whether this defect be equally marked when the charges are confined in drill holes in solid rock." It will be observed that rackarock belongs to the class of explosives invented by Dr. Sprengel and noted on page 670, Vol. VIII of these Proceedings.

For comparison of the relative efficiency of explosives I add the following table taken from Gen. Abbot's *Submarine Mines*, p. 110.

Relative Strength of Explosive Compounds Fired Under Water.

Explosive.	Percentage of nitro-glycerine.	Value of E.	Relative intensity of action. Downward $\vartheta = 0$.	Horizontally $\vartheta = 90°$.	Upward $\vartheta = 180°$.
Dynamite No. 1,*	75	186	100	100	100
Gun-cotton,	...	135	81	87	91
Dualin,	(?)	232	116	111	108
Rendrock,	20	101	67	78	84
"	40	160	91	94	95
"	60	166	93	95	96
Dynamite No. 2,	36	120	75	83	88
Vulcan powder No. 1,	30	99	66	78	83
" " No. 2,	35	114	72	82	86
Mica powder No. 1,	52	119	74	83	87
" " No. 2,	40	46	39	62	73
Nitroglycerine,	100	111	71	81	86
Hercules No. 1,	77	211	109	106	105
" No. 2,	42	118	74	83	87
Electric No. 1,	33	67	51	69	77
" No. 2,	28	43	38	62	72
Designolle,	0	65	50	68	77
Brugere,	0	110	71	81	86
Explosive gelatine,	89	259	125	117	113

* Standard of comparison.



IV
34"x34"
VI
3"
2½"
29"
2"
VI
V
38"
32½"
29"
4½"
I
II
I
32½"
38"
III
4"
1¼"
1½"

NAVAL INSTITUTE, ANNAPOLIS, MD.

October, 1883.

DECK CHART-BOARD.

By Lieutenant Albert Ross, U. S. N.

In the Proceedings of the Naval Institute, Vol. VII, No. 4, 1882, attention was called to this subject, under an article headed "Aids in the Practical Work of Navigation." No working drawings were offered at that time, but a letter containing the principal points of the contrivance, and a model showing the value of ground glass for this purpose, were sent to the Bureau of Navigation, for such action as it deemed desirable. When the working drawings were completed, they were sent to the Bureau, and, as a result of its action, a board was constructed at the Washington Navy Yard for the Swatara, and is now on trial on board that vessel.

As will be seen by the drawing and description, there is nothing about the board that is very complicated, or that cannot be made by the mechanical skill usually found in any of our vessels. The principal cost will be for the glass, which, with proper care, should last through the cruise. Its cheapness, therefore, should commend it for use outside of naval vessels.

In the one sent to the Swatara the parts were made much heavier than was necessary, and which will be remedied in the future. All parts of the wood-work can be made much lighter. The dimensions given in the plates are the dimensions of the Swatara's, but they will give the general idea which it is now desired to convey to the readers of this article. The glass is ¼ in. thick and 34 in. square. One-eighth to three-sixteenths will be found thick enough, if care is taken in the handling. The glass should be ground to order—just enough to show the mark of a pencil will be found to give the proper amount of grinding. This will not obscure any object placed underneath it, as the smallest figures on the chart are

shown very clearly. The glass will have to be ground by hand, as the sand-blast does not pit it uniformly—in some places too much, and in others not enough to show the marks of the pencil. It should be free from flaws and perfectly flat, otherwise difficulty will be experienced in fitting it in the frame and in pressing the chart and glass closely together by means of the screws used for that purpose, endangering the glass on account of unequal pressure caused thereby. The ordinary ground glass of the market, that ground to obscure the light, and used for vestibule doors, &c., can be used in case difficulty is experienced in having it ground to order. In substituting this, the ground face must be rubbed over with an oiled rag that the glass may be used in *fair* weather. The oil will bring out everything with great clearness, and will not affect the pencil marks in the slightest degree. For *wet* weather, however, it is just as good as the glass ground to order, for the wetter it becomes the better it shows. With the glass ground to order, the board is available at all times for work of the navigator in coasting.

From lack of knowledge in the art of glass-grinding, the one sent out was badly scratched, and in trying to get the scratches out, the glass was ground too much for a *fair* weather board. From lack of time another could not be prepared before the sailing of the vessel. Experiments afterwards with ground or powdered glass, similar to that used in the Engineer's Department for grinding in valves, gave successful results. As it may occur that a glass may be broken, in localities where the suitable ground glass cannot be obtained and the clear plate can, the process of preparation of the glass for this purpose may not come amiss. Before grinding, the amount of bevelling of the edges must be done. The edges of the glass in question were bevelled one-eighth of an inch deep and three-sixteenths wide. By the use of files and water this was accomplished; care was taken in filing that it should be done from the edge toward the centre of the glass. By working in this way the glass will flake off in the right direction, and there is no danger of cracking it.

In grinding, the plate glass, with bevelled edges up, is laid on a table, and strips of wood one-eighth of an inch thick nailed around the edges, to keep the glass firmly in place and not allow any powdered glass to get underneath it. The strips being thinner than the glass allow the "muller" to be worked uniformly over every part of it. The "*muller*" is made of copper, similar to those used for grinding paint, or of a piece of plate glass from 6 to 10 inches square,

corners and edges of working face taken off with a file, to prevent scratches that would otherwise be made by the chipping off of the glass; it is then embedded in a block of wood to serve as a handle. The glass is now wet with water, and the powdered glass sifted through muslin over the face. Do not put too much on at first. The muller is then laid on, and with light touch pushed backwards and forwards parallel to the edges of the glass, so that any scratches may be parallel to each other. Then it is changed to work across the first direction, to break up any scratches made. By washing off the powdered glass and testing with a pencil, the necessary amount of grinding will soon be shown. It does not require very much time to complete the work. A trial on a few samples will give an amateur many points in this business, as I found before completing the glass for the Swatara.

The frame was made of black walnut, with secret dovetails at corners. A groove $\frac{1}{2}$ in. wide and $\frac{5}{16}$ inch deep is cut in the top to receive the glass and fittings. Rubber cement was used, but in future rubber strips will be used, as the rubber cement volatilizes and cracks badly, and will not make a permanent water-tight joint. It is necessary that the joint should be flexible, to allow for the expansion of the glass and prevent breakage on that account. The screw holes in the brass plates are countersunk, and when the plates are in place, they and the glass are flush with the top of the frame, thus allowing the parallel rulers to be used over any part without obstruction of any kind. The frame is hinged to the bottom board, or board, as it will be called in the article, in such a way that the distance between the board and glass, when closed ready for use, should be just the thickness of a backed English chart, which is the thickest chart that is likely to be used in the board. The board is $32\frac{3}{4}''$x$32\frac{1}{2}''$. The frame being $33''$ square on the inside, $\frac{1}{4}$ of an inch is allowed on the front, that coast charts, which are about 40 inches long, can be used, by passing the lower end through this space and the space allowed above the box for the same purpose. On the $32\frac{1}{2}''$ distance, $\frac{1}{4}$ of an inch is allowed on each side for charts longer than that distance, to pass into the slots in the rolls, and the ends expended in that way. The charts in the first instance can also be used in the same manner, but the chart will be placed a little awkwardly; $32\frac{3}{4}$ inches was considered sufficiently wide for nearly all of the coast and harbor charts.

The rolls spoken of were placed on the sides of the board, and were, as shown by Fig. VI, made of $\frac{3}{8}$ inch brass tube, $36\frac{3}{8}$ inches long,

with a slot $32\frac{3}{4}$ inches long and $\frac{1}{16}$ wide to receive the ends of single charts or of a continuous line of charts, and then rolled up ready to show any portion of the chart or charts desired. The rolling is done by means of a milled head on the inner end of the tube; the outer end is fitted with a screw to prevent the rolls springing out of the outer board plates. The rolls are held in position desired, by the friction caused by pressure of a collar and washer on the inner board plates. A brass rod, $4\frac{1}{4}$ inches long, with a hole in one end and a screw on the other, is dropped from the outer end through a hole in the large milled head, a pin put through the outer end which catches the washer, and a milled-head screw, shown by the small milled head, is screwed on the inner end. By setting up this screw, the washer and collar on the tube are pressed against the inner board brass, and any amount of friction desired can be obtained. By slacking the friction of one and rolling up on the other, from four to six continuous charts could be placed on the rolls, and any portion displayed. For instance, the charts of Long Island sound, Delaware or Chesapeake bay could be used with great satisfaction. A small crank will be substituted for the large milled head; one describing a circle very little larger than the milled head will perform the work with greater ease. In the wake of the rolls the underside of the board is cut out in order that the capacity of the rolls may be the greatest possible. Dropping the ends of the board plates will increase it if more is desired.

On the inner edge of the board a box $29'' \times 4\frac{1}{2}'' \times 3''$ was fitted, to hold the parallel rulers, dividers, pencil, rubber, &c.; lugs should be fitted for each article, for convenience and safety. The front is hinged to let down, so that the articles named can be obtained without raising the glass. A space one-quarter of an inch is left between the board and box, for the end of charts to pass through. The frame forms, when closed, one half of the lid of this box. This receptacle will be found indispensable, as no convenient ledges are found in the glass or frame to hold anything. The box is secured to the rail brasses with screws.

Fig. I shows two views of the rail brasses, used to confine the board to the rail and press the board and glass closely together. The screw to the right allows the movable piece to drop out of the way, and the board shipped in place when it is secured in position as shown in the plate. The screw to the left is fitted to the frame, and passes through the slot in the end of the rail brass, when a half turn brings

the glass and board close together. These screws have a pitch of four threads to the inch.

I

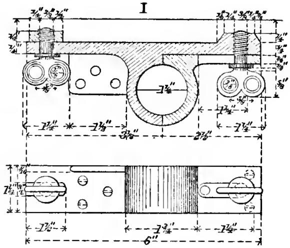


Fig. II shows bronze stanchion collar or strap, made large enough to go over any part of the stanchion, fitted in the end with a milled head set-screw, used in securing for sea, and by setting the collar with it on any point of the stanchion, the angle of the board can be made such as desired. The thumb screw is not a necessity; a bolt similar to the one on the other end of the strut may be used. If the length of the strut is to be the same, and the angle of the board the same at all times, a forked foot to cross the stanchion and a bolt put through would answer the same purpose and be less expensive.

II

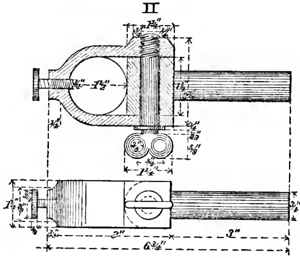


Fig. III shows the arrangement to take the outer end of the strut, when the board is ready for use, and also to secure the board to the stanchion when secured for sea.

III

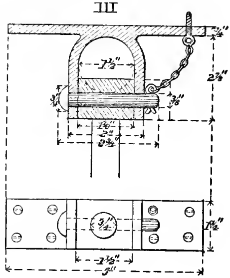
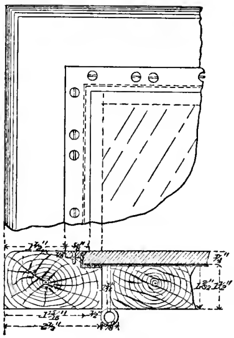


Fig. IV shows the manner of fitting the glass. The glass is bevelled as stated above, rubber cement is placed in a groove in the one-half inch space cut in the top of the frame, the glass put in, and the brass plates covering all of the bevelled edges screwed down, making glass, brass plates and frame flush. The groove is cut to hold the cement, and it is thought that in case it does not work well, sloping holes can be bored for scuppers and the water thus carried off. In fitting the glass, the great necessity for plate glass will be shown; how nicely it will have to be fitted to make it water-tight, and still

IV



have that flexibility necessary to prevent cracking the glass from expansion. The two views will show the plates, and rubber strips that will be used in case of failure of the cement. The glass can be fitted with corner plates, and two-inch plates in centre of each side. This would save a great deal of fitting in the plates and much of the bevelling, which is a great consideration if done with a file, as it would have to be done only in wake of the plates. It is my intention to further experiment with flexible cements, and ascertain the effect of salt water and heat in this direction.

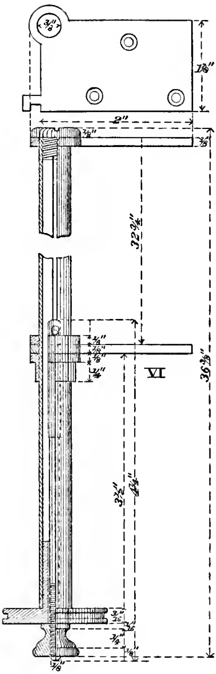
V

Fig. V shows that the board with these fittings can be used wherever a rail and coaming may be found. The carpenter can fit a temporary stanchion of wood, a piece of a boat-hook handle would make a very good one, with two shoes, the upper one with a score to fit the rail, and the lower one flat and large enough to take two or three wood screws to hold it in position. Place the upper shoe with the stanchion fitted in it under the rail, ship the lower shoe, and a few taps of a hammer will put it in position immediately under the upper shoe; secure with the wood screws and the board can be shipped and used.

Fig. VI shows the rolls, manner of construction, dimensions, &c.

If it is deemed desirable that the board should extend inward on the bridge, poop, or other position, fit the rail brasses on the outside of the board, and the strut brass on the inner side. It will then be necessary to fit score brasses on the front of the board, to receive the setting-up screws that are on the frame and used to bring the board and glass together. Some changes may be necessary in the fittings to adapt the board in different positions on board ship, but they can be readily made by the ship's mechanics.

The plate, as shown on the rail to the left, represents the glass raised, and the supports ready for use in direct work on the chart, or to shift the charts. The next plate shows the board secured for sea. The figures indicate the different parts as named in the board. The dotted lines in the third figure show another view of the board as secured for



Full Size

sea, the plain lines representing a section of the board when ready for use, and the manner of fitting the strut, stanchion collar, and outer strut brass. In securing for sea, the lower end of the strut is removed from the stanchion collar, and the board lowered by means of the strut until the bolt can be removed from the outer brace. Push the collar to the top of the stanchion, where it is made fast with the set-screw, let the outer strut brass fall across the stanchion, put in the bolt, and the board is secured for sea. The strut is placed in its collar and the outer end in a hook on the rail.

By the use of the indelible pencils now sold, and damp drawing paper, any object under the glass can be traced, the damp drawing paper laid on and carefully rubbed over with a ruler and the object transferred to the paper. This will be found of great value in many ways, making rough copies of charts in cases of grounding of vessels, getting outline charts, and in other ways that will readily come to the mind of those experienced in the handling of charts.

No lighting apparatus was fitted to the Swatara's chart-board. In ships not having electric lights, a small brass crane will be fitted on the outer edge of the frame, from which will be suspended a lamp, with a reflector so arranged that the whole surface of the board will be illuminated, and at the same time the light so hooded that it will not show outside of the desired point. In fair weather, and when it is desired to raise the glass, the lamp can be hooked to the frame when raised. In ships with electric light, one incandescent burner, hooded in the same way, will be found sufficient to accomplish this purpose. A much better plan, which is now under consideration, is to fit a plate of plain glass in a frame to take the place of the board, under which will be placed in a suitable receptacle a sufficient number of incandescent burners to illuminate the chart from underneath. Some of the thick charts will require special preparation for this

work, but charts are now issued by the Coast Survey that can be used in this manner with great satisfaction.

When the glass is raised for the purpose of shifting the charts, or for direct work on the chart, supports made of flattened tube are fitted to the frame. In the lower end a slot one-half inch long and one-eighth wide is made, with an opening cut into the middle of the slot, to take the catch on the ends of the inner board plates. The slot and opening are made in this way to prevent the frame being blown over when raised, the lower end of the slot catching and holding it in place.

In making this board it was my object to adapt it to the general charts now in use. That many changes can be made to secure greater uniformity in size, &c., no one will deny, and, for the convenience of navigating officers, it is hoped that this subject will receive attention. With charts of uniform size, continuous lines of charts could be kept together on rolls, and by a slight alteration in the roll mechanism, a new roll could be exchanged in a very short time. Chesapeake and Delaware bays would each be in one roll, Long Island sound in another. The charts of all inland waters should be in separate rolls.

The great necessity for a contrivance of this kind and its value will be thoroughly appreciated by any one who has had to deal with charts in bad or windy weather, on approaching the coast. With ordinary vestibule glass, that which is ground to exclude the light, no difficulty will be experienced in its use for a *wet weather* board; for the wetter it becomes the better it is for the purpose desired. Grinding to order will give a glass that can be used in fair or foul weather. In the later samples, ground with powdered glass, the object placed underneath was not obscured, and the pencil marks of plotted bearings were as readily discerned as could be desired by the most exacting navigator. In fair weather the bearings can be plotted and all work done on the glass in the same manner as has been formerly done on the chart. Thus the charts will be kept much cleaner, freer from grease spots from leaky lamps, from holes *punched* in the chart, and will be better preserved in every way. Of the great value in wet weather of the described chart-board I think none will gainsay, as the chart will be kept on deck in the best position possible, and can be approached at all times without fear of wetting it. The valuable time that is usually lost in running below to the cabin table and having to remove rain clothes before the chart can be consulted, will be spent on deck, where the whole situation is spread out amidst the war of the elements.

PROFESSIONAL NOTES.

ELECTRICITY APPLIED TO EXPLOSIVE PURPOSES.

By Sir Frederick A. Abel, C. B., F. R. S., Hon. M. Inst., C. E.

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Although the subject which has been entrusted to me may not lay claim to such general public consideration and interest as those which have been so successfully and attractively dealt with by my colleagues, it certainly should not rank behind them in importance to such an audience as I have the honor of addressing; for the application of electricity to the development and efficient utilization of the force of explosive agents has proved of great value to every branch of engineering science,—civil and military, mechanical and mining,—while even the telegraph engineer has been concerned in the employment of explosives through electrical agency for the transmission of time-records.

The ignition of a charge of explosive through the agency of a match, a powder train, or a slow-burning fuse, though still very extensively practiced in mining and blasting operations,—and likely to continue so, on account of its comparatively simple and inexpensive nature,—presents such decided disadvantages in point of uncertainty, and, in some cases, of danger, when compared with the operation of firing by electricity, that it is not surprising to find on record, at an early period in the development of electrical science, attempts to apply an electric spark, or the heat developed by electrical currents under certain conditions, to the ignition of powder-charges. But it is especially in connection with the firing of charges under water, and with the execution of extensive operations of mining or demolition, when the safety of the operators can only be secured by their being at a considerable distance from the scene of operation at the time of the explosion, or in which the simultaneous explosion of a number of distinct and more or less separated charges is a matter of importance, that the value of electricity as an exploding agent is manifest. The mining fuse patented by Mr. Bickford in 1831 effected an enormous improvement in the firing of mines, and failures with it are comparatively rare, unless it has deteriorated from careless keeping, or from the use of an imperfectly protected fuse in damp or wet places. But even with this improved fuse in general use, many a fatal accident in military and industrial operations has resulted from the hanging fire of the fuse, and many failures and delays of vital consequence have resulted from the occasionally uncertain and capricious nature of igniting appliances of this class, and from the impossibility of ascertaining, when all arrangements are complete, whether the explosion prepared for will actually take place.

The possibility of applying the electric spark to the ignition of gunpowder suggested itself independently to Franklin, in America, in 1751,* and to Priest-

*In his "Letters on Electricity," dated 29th June, 1751, Franklin says: "I have not heard that anybody in Europe has yet succeeded in firing gunpowder by means of electricity. We do it in this way: a small cartridge is filled with dry powder, which is rammed in tightly enough to crush a few grains; two pointed brass wires are then fixed in it, one at each end, so that their points are not further apart than half an inch at the centre of the cartridge, which is then placed in the circuit of the electric machine; when the communication is completed, the flame, leaping from the points of one wire to that of the other through the powder in the cartridge, fires it instantaneously."

ley in 1767; but it was not until some years after the discovery of the electric pile by Volta that serious attempts were made to apply electricity as the igniting agent of powder-charges used in mining and military operations. The first practical application of the voltaic battery in this direction was made about forty-five years ago by French military engineers, and a few years afterwards Sir Charles Pasley, whose name is so well known in the engineering world, was the first to bring the use of electricity in the firing of gunpowder to a practical issue in England. The art of firing powder-charges under water was in a very backward state when Colonel Pasley first made it the subject of practical investigation in 1812, and, finding that the slow-burning fuse subsequently invented by Bickford could be used only at comparatively small depths with any prospect of success, he devised a fairly efficient arrangement of powder hose, which could be led to considerable depths, and which he employed with some success in operating upon the wrecks of the Royal George and Edgar, which were submerged in deep water off Spithead. It was while engaged in this work that Pasley, profiting by the counsels and instructions of Daniell and Wheatstone, carried out between 1835 and 1840 the first blasting and mining operations by electrical agency which were accomplished on a practical scale in this country.

The Daniell battery was used in the earlier of these operations, upon the Royal George at Chatham, and upon some wrecks in the Thames, and some decided progress appears to have been made in blasting by electric agency; but in 1840 General Sir John F. Burgoyne, writing on the subject of rock-blasting in the Corps Papers of the Royal Engineers, said: "The distinct machinery for this purpose (firing by a voltaic battery), the expense, and probably some degree of nicety in its arrangements, even after all the improvements that have been made by Colonel Pasley, would render it inapplicable to ordinary purposes; although for firing very large quantities of powder, under very peculiar circumstances, it has been considered very useful, . . . simultaneous explosions, that are impossible by any other means, might be effected by this mode of ignition."

In the winter of 1842–3, experiments were instituted at Dover with the Daniell battery upon a considerable scale, preliminary to the explosion of the great mines, by which the destruction of the Round Down Cliff was accomplished on the 26th of January, 1843, when more than 40,000 cubic yards of rock were dislodged by the explosion of three chambers containing 18,500 lbs. of powder. A large copper and zinc-plate battery, on the Wollaston principle, was actually used for that work, and was employed in subsequent operations upon the Royal George, it being found to possess decided advantages, in point of power and simplicity, over the Daniell battery. In the concluding operations upon the wreck in 1843, a zinc and iron battery was successfully applied to the simultaneous explosion of several large charges. The conducting wires leading from the battery to the mines, in those experiments, were not insulated by means either of gutta-percha or india-rubber; they were composed of strands of copper wire placed side by side, and insulated from each other and from the water by being coated with a mixture of beeswax, pitch, and tallow, and then bound over with layers of tape and twine, or rope-yarn. As acquaintance with the work became developed, the entire metallic circuit was dispensed with after a time, and the circuit was completed through the water, the surface of the metal case enclosing the charge being employed as one earth-plate, and large zinc sheets as the other.

The general method of operating pursued at that time by our military engineers was adhered to with little modification for many years. In the centre of the charge of gunpowder was placed a so-called burster or fuse, a small box or case of wood, with two short copper wires passing to the interior and firmly fixed, the enclosed extremities being connected by a short bridge of thin wire, composed of metal of inferior conducting power; iron in the first instance, and afterwards platinum, which was surrounded by very fine grain powder. The

protruding extremities of the copper wires thus arranged were connected with the terminals of the circuit-wires by means of binding-wire, the connections being covered with insulating wrappings. The heating to redness of the fine wire-connection or bridge (or its fusion, in the case of iron being used), consequent upon the resistance which it opposed to the current, ignited the fine grain powder by which it was surrounded, and the charge was thereby exploded. Simple self-acting arrangements were used for causing the battery-wires to be short-circuited for a sufficient time after the arrangement of a mine was completed, to allow the operators to reach a place of safety, the current passing through the entire circuit, and thereby firing the fuse, at a fixed period.

In an interesting memoir on the explosion of powder, written in 1845 by Captain Hutchinson, R. E. (now General Hutchinson, of the Board of Trade), and published in the "Aide Mémoire to the Military Sciences," the forms of battery successively tried in connection with the earliest experimental operations, and with the destruction of the Royal George and the Round Down Cliff, are described, as also the methods used for preparing insulated wires, electric fuses or bursters, and charges for submarine operations; for firing the charges by self-acting arrangements, and for testing the circuit and the fuses, before combining them. For the latter purpose the use "of the instrument called the galvanometer" is prescribed, as affording the readiest mode of testing; the action of the needle is stated to be more readily visible if the coil surrounds it vertically, and the test-battery prescribed is either "a small plate of zinc within a copper case," or a "small single cell of a Daniell battery, by which the action will be much longer kept up, and the zinc will not so soon perish." The "water-test apparatus" (voltameter) is also indicated as another method of "proving the completeness of a circuit, requiring, however, a more powerful battery, and not being so quickly performed as by the galvanometer." The methods of working pursued in 1843 at Spithead, at the Phœnix Park operations of Captain Larcom, and at the Round Down Cliff, are also described. At the latter place they consisted simply in firing the individual charges by separate batteries through wires 1000 feet long, by word of command; but in the other operations the charges were connected by branch-wires with the main wires, either by attaching them with binding-wire, or binding-screws, to those wires at convenient intervals, or by leading one wire from each charge to a mercury-cup, and the other wire to a second cup, the bare extremities of the double main wire being immersed in the two cups, when it was desired to complete circuit with battery. This method of arranging the charges in branch or fork-circuits, by which the current is made to distribute itself so as to heat the wire bridges introduced into the several circuits simultaneously, was afterwards applied by the French electrician, Savare, for utilizing a rapid succession of currents of high tension, as will be presently pointed out.

As a whole, the manner in which the operations of forty years ago were carried out evinced a sound knowledge of the principles of electrical science, and considerable practical skill and ingenuity in their application by the Royal Engineer officers who devoted themselves to this work.

The copper-zinc battery continued for some time in use as the exploding agent for military service, but some improvements were gradually introduced into the methods of operating, by Royal Engineer officers. Colonel Ward, more especially, did very useful work in this direction, and published in the "Aide Mémoires" of the Royal Engineers for 1854, the results of a very careful investigation of the merits of different batteries, and of the conditions to be fulfilled in operating through different lengths of wire-circuit, with details on the construction of the fuses and arrangement of charges for simultaneous explosions, and other important points. One result of his labors was the adoption for military service of a form of Grove battery specially adapted to work of this kind, which, with the rough form of platinum-wire fuse described, continued in use until, soon after a report by Sir C. Wheatstone and the Lecturer was presented to the War Office, in 1860, (which will presently be referred to

again), instruments developing currents of high tension gradually displaced voltaic batteries as exploding agents.

Although the employment of a voltaic current of low tension presents obvious and great advantages over old systems of igniting charges by trains or slow-burning fuses, its application to military purposes is attended with some difficulty and uncertainty, arising out of the want of uniformity of action of one and the same voltaic arrangement at different periods, the difficulties attending the transport and proper preservation of the battery and materials required for its use, the dependence for success upon care and experience in preparing and preserving the batteries, and the very considerable increase which it is necessary to make in the power of the battery when the operations to be performed involve the simultaneous explosion of a number of charges, or the ignition of gunpowder at very considerable distances from the battery.

Thus the Grove's battery, as arranged by Colonel Ward, though efficient when in thorough working order, possessed the very serious defect of want of constancy; within a comparatively brief period of its being set in action, even though not actually at work, it began to lose power to a certain extent, and in order to place proper reliance upon its efficiency when called into operation, it had to be dismounted, cleaned, and remounted, at least every twelve hours, so that, besides maintaining a large reserve of the difficultly transportable porous cells, it was necessary, on active service, to provide the requisite battery-power in duplicate, besides using a number of cells considerably in excess of the theoretical requirements.

For reasons of this nature, soon after the first successful application of voltaic electricity to mining purposes, the attention of military engineers on the Continent, and of others here and abroad who were specially interested in operations of this kind, became directed to the possibility of rendering electricity of high tension available for exploding purposes, whereby voltaic batteries, for mining operations, might be greatly reduced in size, if not altogether dispensed with. In 1853 a Spanish officer, Colonel Verdu, associated himself with M. Ruhmkorff in experiments on the application of electro-magnetic induction coils to the explosion of gunpowder. The success of these experiments led Verdu to pursue them further in Spain, where he soon succeeded in firing six mines simultaneously by one element of Bunsen's battery, at a distance of upwards of 300 yards, through the agency of the Ruhmkorff coil. The mode of operation and the difficulties which Verdu had to overcome will be presently described. While his success led the military engineers in Spain, France, and Russia to pursue the development of the application of electro-magnetic induction-instruments to exploding purposes, a committee of Austrian military engineers (of which Baron von Ebner was from the first a most distinguished member) was laboring to apply frictional electricity to military uses as an exploding agent, they having come to the conclusion that the electro-magnetic induction apparatus was too complicated and too easily susceptible of derangement for military uses.

But little success had, up to that time, attended attempts to apply frictional electricity to this purpose. In 1831 Moses Shaw, of New York, succeeded in exploding several mines simultaneously by means of frictional electricity, with the employment of fuses containing an admixture of fulminate of silver with gunpowder; but he was foiled in his attempts to apply this agent to practical purposes by the fact that he could not conduct operations with any chance of success except in very dry weather. Somewhat more promising results attended several attempts in Germany by Warrentrap and Götzmann, between 1842 and 1845, and in the latter year Mr. Charles Winter succeeded in firing a powder-charge by means of a sensitive fuse and a Leyden jar through the telegraph line between Vienna and Hetzendorf—a distance of 5390 yards. But the prospect of practical success was still not encouraging when the Austrian committee of engineer officers took the matter in hand, and eventually produced a portable glass frictional electric machine, which, when in good work-

ing order, furnished results surpassing those hitherto obtained with volta-induction apparatus. Some very extensive operations were conducted with this machine. Thus, fifty land-charges, and afterwards thirty-six submarine charges, were simultaneously exploded. Even, however, with all the precautions adopted, the machine was still too seriously affected by damp to be thoroughly serviceable for military purposes, while the induction action of the firing-charge was sometimes so energetic that explosions were occasionally determined in mines not intended to be fired, and not connected with the electrical machine. But the persevering labors of Von Ebner eventually resulted in the production of an electric machine which was free from most of the objections hitherto attached to this form of apparatus.

While the progress just indicated was being made in different parts of the Continent in the application of electricity to mining operations, but little was done in this country towards effecting radical improvements in the utilization of electricity for industrial or military mining purposes. In 1855, however, Sir C. Wheatstone directed the attention of Field-Marshal Sir John F. Burgoyne to the importance of instituting an experimental inquiry into the relative advantages of different sources of high-tension electricity as agents for exploding gunpowder. The Ordnance Select Committee, of whom Sir C. Wheatstone and Mr. Abel were then members, were consequently instructed to pursue this inquiry; and a series of investigations was carried out—in the first instance by a working branch of the Committee, and subsequently by Mr. Abel at Woolwich and Chatham—the results of which were eventually embodied in a report presented by the above-mentioned gentlemen to the Secretary of State for War in 1860.

Meanwhile, the subject of the application of electricity to the firing of mines, &c., continued to receive attention in Austria and other countries, and considerable impetus was given to work in this direction by the efforts of the two opposing powers in America, between 1862 and 1865, to apply electricity as the exploding agent of submarine mines, the prominent part played by these in the Civil War having had the effect of directing the attention of England and other nations to the prominent *rôle* likely to be played in future wars by methods of submarine attack and defence, and to the importance of applying the resources of electrical science to their development.

Before glancing at the important applications of electricity in this and similar directions which have been made and perfected during the past eighteen years, it will be instructive to examine briefly the results obtained with different sources of electricity in their application to explosive purposes, and the manner in which electric currents or discharges are made available to the explosion of powder under the various conditions and difficulties to be met in the fulfilment of military and industrial requirements.

It has been stated that Colonel Verdu succeeded, in 1853, in exploding several mines simultaneously by means of a Ruhmkorff induction-coil. The ignition of the gunpowder was effected in these experiments by introducing one or more small but complete interruptions into the circuit, across which the electric spark of high tension would leap upon the current being passed. This spark will inflame gunpowder, but not very readily, although its production is attended with development of heat considerably in excess of that necessary—the reason being that powder requires for its ignition either the close proximity of a considerable heated surface, or the continuous application of heat for a brief period; while the disruptive discharge from an induction-coil consists of a series of instantaneous discharges following each other in very rapid succession. Hence a charge of gunpowder is not always instantaneously fired when a series of sparks is passed. Indeed, unless the powder be closely confined round the wire terminals between which the spark passes, it is sometimes dispersed by the mechanical action of the discharge without being exploded; and, when a succession of sparks is passed simultaneously through a number of

charges, it frequently occurs that only a few are exploded, in which some of the grains happened to be in positions or under conditions more favorable to the action of the source of heat than in other instances where the powder escaped ignition. It need scarcely be stated that the same difficulty is experienced in attempts to apply the discharge from a frictional electric machine or Leyden jar to the explosion of powder. Moses Shaw was the first to overcome it by exposing to the action of the spark a mixture of powder with a much more readily-explodable material. Verdu succeeded similarly in increasing the certainty of simultaneous ignition of several charges by the spark from an induction-coil machine, by surrounding the wire terminals with a substance much more readily inflamed than powder, the fulminate of mercury. Another source of difficulty in effecting the simultaneous ignition of a considerable number of charges by the spark from an induction-coil is the enfeebling effect upon the spark-discharge exerted by a number of successive small interruptions in the circuit. This was to some extent overcome by employing a fuse constructed by Messrs. Statham and Brunton, in which the space between the wire terminals was bridged over by a film of finely-divided substance—the subsulphide of copper, the conducting power of which is sufficiently great to aid the passage of the electric discharge across the interruption, while it is at the same time readily combustible, and therefore directly promotes the ignition of the powder.

The invention of the Statham and Brunton fuse may be regarded as the starting-point in the production of so-called high-tension fuses, as contra-distinguished from the thin wire or low-tension fuse, and the circumstances which led to its construction therefore present special interest. In August, 1851, a length of copper wire which had been covered at the Gutta-Percha Company's Works with gutta-percha containing about 10 per cent. of sulphur, was being passed through water from one reel to another for the purpose of discovering what appeared to be a fault in insulation, when suddenly a bright spark was observed in the water. On examining the wire at that particular spot it was found to be broken and the gutta-percha burnt. Several pieces of similarly-covered wire were then purposely broken, in each case with similar results. A length of the gutta-percha was then removed from the wire, and on applying the two poles of one hundred cells of the battery in use at various distances to the inner surface which had been in contact with the copper, and had become coated with a film of sulphide of copper,—which, in comparison to copper, is of very high resistance,—heat was generated, in proportion, of course, to the distance of the poles. Gunpowder was placed upon the gutta-percha, and, on applying the battery-poles, it was immediately ignited. Consequently, by removing a small portion of the gutta-percha from the upper surface of the wire, then severing the latter at that point and slightly separating the two extremities, a suitable fuse for igniting explosive substances at long distances, and simultaneously at several points, was produced. When the cable was laid from Dover to Calais, in September, 1851, cannon were fired by the aid of these fuses at Dover by a person at Calais, and *vice versâ*. Also when the first Mediterranean cable was laid from Spezzia to Corsica, a distance of 90 miles, similar experiments were successfully made.

Colonel Ward, in his important paper already mentioned, on the application of the voltaic battery to the explosion of powder, carefully examined into the properties of this fuse, and compared its behavior with that of the wire fuse. He pointed out that, while the amount of heat required to ignite the sulphur and copper compound formed on the surface of the gutta-percha was very much less than that needed for firing a platinum wire-fuse, the conducting power of the substance was very low; but that whatever number of cells, roughly speaking, it is found necessary to arrange in series to produce ignition of the fuse at a distance of one foot by conduction of the current across the interrupted metallic circuit bridged over by the sulphide, will produce the same effect through a copper wire circuit of one mile, and that an addition of

about one-fourth the number of cells of the battery will permit one-half of the copper circuit to be replaced by ordinary moist earth, the resistance of the fuse being so great that a large addition to the metal circuit, or the introduction of a great distance of earth-circuit, effects no material diminution in the actual quantity of electricity circulating. The battery used by Ward in his instructive experiments with these fuses was a zinc and copper sand battery 4 inches by 4 inches, of which one hundred plates were needed to fire the fuse with certainty, while three hundred plates of the same battery were not found to develop any sensible heat in the platinum wire-fuse; and he pointed out the important bearing of the internal resistance of this battery upon the attainment of these results. He also showed that, while the diameter and material of the metallic conductor are matters of material consequence in using the platinum-wire fuse, it is of no consideration to know the resistance of the conductor in the case of the Statham-Brunton fuse. On the other hand, he insisted upon absolute insulation of the conductor as essential to the successful employment of this fuse.

While Ward was engaged upon experiments with this fuse in 1854, it was demonstrated to him by the late Mr. Southby, a well-known pyrotechnist, who devoted himself much to experimental electricity, that the current induced in a secondary coil wound round a helix of the primary conductor through which the current from three or four cells of a Grove's battery was passed, sufficed to ignite the Statham-Brunton fuse. Ward found that, with such a helix and four cells of Grove's battery 4″ × 4″, he could fire the fuses at a distance of 1300 yards from the operator (the longest distance he was able to try), and with the employment of a return earth circuit. These results were therefore obtained in England concurrently with, if not before, those which Colonel Verdu obtained with the excellently constructed coil of Ruhmkorff.

The employment of the Statham fuse for effecting simultaneous explosions was not pursued to any great extent by Ward; but so far as his experiments went, with the use of the sand battery, he found that the difficulties were much greater than those to be encountered with the platinum-wire fuse. Even with the use of the Ruhmkorff induction-coil, and with a priming of mercuric fulminate added to the Statham fuse, Verdu found that the number of charges which he could fire simultaneously was very limited. He was, however, able to obtain a fair result by the following simple arrangement. Separate small groups of mines were all connected with earth, and an insulated conducting wire connected each group with one of a series of small insulated plates. By bringing these in very rapid succession into circuit with the coil-machine, the several groups were so rapidly exploded as to produce results somewhat similar to those attainable by the really simultaneous discharge of a considerable number. Not long after this contrivance was adopted by Verdu, Savare applied the so-called branch-circuit arrangement, whereby a much more rapidly successive discharge of a number of mines was accomplished through the agency of the coil. The metallic circuit which passed to the mines was divided into a number of branches, so that upon completion of the circuit the currents, following each other in very rapid succession, would distribute themselves through all the branches with a degree of uniformity regulated by the resistance met with in each branch. Thus, when one or more fuses were interposed in each branch of the circuit, those which happened to offer the greatest facilities for the passage of the current would be first fired, whereupon the escape of electricity in that direction would be interrupted, and the explosion of fuses in another branch would follow. With the employment of currents succeeding each other with the enormous rapidity with which they pass off from the induction-coil machines, the discharge of a number of mines is thus accomplished in such very rapid succession as almost to have the effect of a simultaneous discharge. It will be seen that this arrangement is the same in principle as that used by Royal Engineer officers in England and Ireland in 1843, when first the voltaic battery was applied to the ignition of powder.

The Ruhmkorff coil was used to some extent by the Russians in mining operations during the Crimean War, and some very extensive operations were carried out with its aid at Cherbourg in 1854 by Dussaud and Rabattu, according to a system arranged by Du Moncel. In the first of these, six mines, containing many thousand kilogrammes of powder, were simultaneously exploded, displacing more than 50,000 cubic metres of rock. A series of experiments was instituted by the lecturer in 1856 with two excellent induction-coils, produced by Ruhmkorff, in the course of which various descriptions of priming materials were tried in the fuses for the purpose of increasing the power of the machine to fire numbers of charges simultaneously. At that time the fulminate of mercury was found to be the best inflaming agent, but not more than twelve charges were fired simultaneously by means of the most powerful coil available and a battery of twelve cells (without employing Verdu's or the fork-method of explosion). One defect in this class of instrument was found to be the want of uniform action of one and the same apparatus at different periods; another was the liability to derangement of the machine, especially of the condenser. Far more successful results were afterwards obtained with the same coils, and the fuse constructed at a later period of the Woolwich investigations; fifteen charges were fired simultaneously with a battery of six cells, and fifty charges, arranged in branch circuits in groups of ten, were exploded with the effect of a simultaneous discharge. These results were obtained with machines produced by Ruhmkorff in 1855; but the improvements since then effected in the construction of this apparatus have reduced to insignificance the results at that time obtained with it. There is no question, therefore, that induction-coil machines are available for special operations of considerable magnitude; but in point of simplicity, certainty, and constancy of action, they are far surpassed by other forms of electric instruments now in general use for explosive purposes.

At the suggestion of Sir Charles Wheatstone, experiments were commenced at Woolwich in 1856 on the application of currents induced by permanent magnets to the explosion of gunpowder. The first were instituted with a very large and powerful magneto-electric machine, constructed by Mr. Henley, of which the armature, carrying two powerful coils, was suddenly detached from the magnet by means of a lever. A few experiments sufficed to show that the induced current obtained even with this powerful instrument was not adequate to ignite one single charge of gunpowder with certainty. Somewhat better, but still uncertain, results were obtained with Statham's and one or two other forms of fuses existing at that time.* A careful investigation was then undertaken by the lecturer (with the invaluable assistance of Mr. E. O. Brown) into the conditions to be fulfilled in the production of a fuse which should be certain of action with the magneto-electric machine. The results of extensive experiments indicated that a combination of comparatively high conducting power with great susceptibility to ignition appeared to include essential elements of success in a material to be used as the exploding agent in such a fuse. The uniform arrangement of the poles, or wire terminals, in the fuse, the space between which was to be bridged over by the igniting composition, also proved a matter of great importance. A mode of constructing fuses which ensured great uniformity in this respect was ultimately perfected, and has proved quite successful. This consists in the enclosure of two fine copper wires side by side in gutta-percha, by which material they are also uniformly separated from each other, so that great similarity as to distance between the poles, or exposed sections of the wires, is attained by simply cutting pieces of the double-covered wire off a long length of the same.

A fairly efficient fuse was obtained, with the aid of the poles thus arranged, by employing as the igniting agent gunpowder impregnated with a small proportion of calcium chloride, which caused it, on brief exposure to air, to imbibe

*A fuse which gave better results with this magneto-electric machine than any then existing was prepared by the late Mr. Henley. Its nature was not, however, disclosed by him.

moisture sufficient to render the gunpowder highly conducting. It is obvious, however, that there must be a liability to want of uniformity in the proportion of water absorbed by the powder, and a consequent variation in the conducting power of the latter. Eventually a material was prepared (consisting of the sub-phosphide of copper, sub-sulphide of copper, and potassium chlorate) which combined the essentials of perfect certainty of action with very great sensitiveness to ignition. Henley's large magnet fired three of these fuses in simple circuit with certainty, while a small horse-shoe magnet with revolving armature exploded twenty-five in divided circuit in exceedingly rapid succession. A combination of six small compound magnets was afterwards employed, with which an exceedingly rapid succession of currents was obtained; and this apparatus exploded twenty-five fuses, in divided circuit, with a rapidity which on the ear had the effect of an instantaneous explosion. Even the small magneto-electric instruments used for medical purposes will explode these fuses without fail.

It may be mentioned, in illustration of the difficulties to be grappled with in such an inquiry as led to the production of this fuse, that the first phosphide of copper mixture employed in the priming of these high-tension fuses contained finely-divided coke as the conducting medium (in place of the sulphide of copper afterwards used), and that, so far as uniformity and permanence were concerned, this mixture left little to be desired. But in the course of searching experiments with such fuses, a slight residue, consisting chiefly of the coke employed, was found occasionally to remain between the closely contiguous poles of the fuse, after its ignition, and to form a connecting link or bridge between them, which interfered with the firing of other fuses in the arrangement, by completing the circuit through that one, and thus preventing the rapidly successive currents from a magneto-electric machine from performing work upon others in branch-circuits. The substitution of the readily-combustible and dispersable sub-sulphide of copper for the coke conquered what appeared likely to prove a formidable difficulty.

The application of magneto-electric machines having been successfully accomplished, a series of experiments was carried on by the lecturer, with the valuable aid of General H. Y. D. Scott, R. E., at Chatham, during the years 1857–58, on the explosion of charges, both land and submarine; and the great advantages of these instruments, as regards simplicity and permanent efficiency, over the voltaic arrangements then in use, was fully demonstrated. Very compact but powerful exploding instruments were constructed by Wheatstone, and these have received many important applications. Thus, the proof of cannon at Woolwich and the firing of guns, from a safe distance, in the numerous experiments at Shoeburyness, is effected by means of Wheatstone's exploder, which is, moreover, an important adjunct in all electro-ballistic experiments, when the operator desires himself to fire a gun at a particular moment. Magneto-electric machines have also been found very useful in connection with blasting operations on land and in mines, except in instances when the absolutely simultaneous explosion of a large number is required.

When the success of Wheatstone's exploders had been fully established, several other forms of magneto-electric machines were devised, especially on the Continent and in America. Powerful instruments, similar to Wheatstone's, were manufactured by Siemens and Halske, of Berlin; Markus, of Vienna, constructed very efficient instruments in which one separation and return of the armature to the magnet are made to explode the charges. The disadvantages of these instruments is that a succession of currents cannot be obtained from them as in the case of machines with revolving armatures; hence the number of mines which can be exploded by them in divided circuit is limited. Mr. Beardslee, an American electrician, also devised a modification of Wheatstone's exploder, in which the magnets are made to revolve between the armature coils, and which furnishes currents of greater quantity but lower tension than Wheatstone's. A fuse was constructed by Beardslee for employment with

this instrument similar in principle of construction to Abel's; the materials which bridge over the space between the terminals or poles of the fuse are blacklead, with the addition of a minute quantity of a substance, apparently collodion, which adds to the size of the scintillations produced when the current passes, and thus increases the certainty of ignition of the powder, which is in close contact with the poles. These fuses are efficient with magneto-electric instruments, which, like that of Beardslee, furnish currents of comparatively low tension, but they are much less delicate than the Woolwich fuses, and the number which can be simultaneously exploded is therefore more limited. Wheatstone also constructed more powerful modifications of his original magnetic exploder, which might at will be made to furnish currents of greater quantity and lower tension, or to produce the high-tension currents. Lastly, Ladd, Browning, and Breguet produced instruments of comparatively low price, but quite powerful enough for ordinary blasting and quarrying operations. The only obstacle, but a most important one, to the general use of these machines for the explosion of mines on land and under water is, that very slight defects in the insulation of the conducting wire which leads from the instrument to the mines are fatal to their exploding power. In consequence of the high tension of the current developed by them, and the small quantity put into circulation by even the most powerful, the complete diversion of the current from its destined course to earth is promoted by the smallest points of escape presented to it; a result which is, moreover, facilitated by the very high resistance of the fuses in circuit. With care this source of failure can be guarded against in operations on land, but such is not the case with regard to submarine arrangements; while, moreover, very minute defects in the coatings of the wires when submerged, which would hardly influence the results at all on land, completely nullify the exploding power of the machines. Hence, magneto-electric instruments are the least reliable of all electric exploding apparatus for submarine purposes.

A few experiments were instituted at Woolwich in 1857, on the employment of frictional electricity as an exploding agent, and especially with a small hydro-electric machine constructed for the purpose by Sir William Armstrong. The power of this machine to explode a number of charges simultaneously, when it was in good working order, far surpassed any other instrument experimented with at that time; one hundred fuses, arranged in simple circuit, were frequently exploded by its means; but the great uncertainty of its action, and the difficulty of employing it in the field, did not afford encouragement for continuing experiments with it.

The great difficulties encountered in the Austrian experiments, in attempts to employ glass frictional electric machines for military purposes, led Baron von Ebner to direct his attention to the production of an instrument in the construction of which glass was altogether avoided, and which might therefore be expected to be less subject to atmospheric influences. His labors in this direction were eventually crowned with success; for he found in the hard vulcanized india-rubber (known as ebonite or vulcanite) a dialectric material excellently adapted to the construction of the frictional apparatus; while by employing a sheet of soft vulcanized india-rubber, coated with tinfoil and compactly rolled up, he obtained without the use of glass a powerful condenser, or Leyden jar arrangement. The improved machines were constructed in a very compact form (with cases excluding all the working parts from direct exposure to air) by Messrs. Siemens of Berlin, and Lenoir of Vienna, who exhibited specimens in England in 1862, at which time the electric machine had already received important applications, and been regularly adopted for military use in Austria. Von Ebner had also, from the commencement of his experiments, labored assiduously at the production of an efficient fuse to be used with electricity of tension; and the Austrian service is indebted to him for a simple and thoroughly serviceable fuse, which, as regards the arrangement of its poles, and the character of the igniting composition, may be said to combine the

principles of the Statham and the Abel fuses. Though much less sensitive than the Abel fuse, a very considerable number may be exploded in single circuit by the ebonite electric machine. The power of this apparatus in its most portable form is nearly equal to that of the hydro-electric apparatus just now referred to, when the latter was in perfect working order; and a far greater number of mines may therefore be simultaneously exploded by its means than by very large batteries, or by the most powerful portable magneto-electric machines hitherto constructed. One hundred Abel fuses have frequently been simultaneously exploded with one of the portable machines, and still greater results can be obtained with a larger instrument, having a battery of condensers, which was specially constructed by the late Mr. Becker, at the suggestion of Captain Maury, and designed for use in connection with land and submarine mines. In very damp weather, when the most perfect glass electric machines would have been useless unless housed in a warm apartment from which the external air was excluded as much as possible, these ebonite machines have been used from time to time throughout the day with very satisfactory results.

Another important advantage which they possess over magneto-electric machines, consists in the fact that very considerable defects in the insulation of even submerged conducting wires do not so greatly reduce the power of the current they furnish as to interfere with the accomplishment by its agency of the most extensive operations under water likely to occur in practice. Unfortunately, however, the very circumstance which constitutes their chief advantage, viz. the powerful character of the current of high tension with which they charge an insulated wire, is also a source of serious defect, to be presently noticed, which very greatly limits the usefulness of these machines for naval and military purposes.

Other more recent Continental and American forms of frictional machines constructed of vulcanite or ebonite, in some of which fur is used as the exciting agent and different forms of condensers are employed, are in favor in different countries or mining districts. One of the most compact and efficient exploding instruments, excellently illustrating the simplicity to which machines of this class can be reduced by ingenuity and a thorough knowledge of the conditions to be fulfilled by a really practical apparatus, is the frictional electric exploder, manufactured of various dimensions by Laflin and Rand, of New York, in the form of an ebonite cylindrical box (or disk), on which the only protruding objects are the connecting screws for wires and the handle for working the machine. When the handle has been turned sufficiently to charge the enclosed condenser, a reversal in motion of the same discharges the latter and fires the mine. This machine has been found specially valuable in boat-work, under conditions when it would have been very difficult to use any other form of frictional machine, and when other electric exploding apparatus depending for their operation upon mechanical arrangements, more or less accessible, would have sustained injury from the effects of contact with water, or an atmosphere laden with moisture, or salt-water spray.*

Although ebonite frictional electrical machines held their own for some considerable time, as the most powerful and generally effective exploding apparatus, for extensive operations, they had to make way for a class of machine, which, as combining general efficiency with simplicity, power, permanence, and independence of any influence emanating from atmospheric or local conditions, now occupy decidedly the highest position as practically useful agents for developing explosions. It is scarcely necessary to say that the machines referred to are those known as dynamo-electric, the first conception and elaboration of which we owe to Werner and William Siemens, Wheatstone, and others.

*One defect of ebonite in its application to the construction of frictional machines, is that the surface becomes roughened and worn after a time by the amalgam used in the cushions, so that the disks require repolishing occasionally.

The action of the most simple form of these instruments may be described as follows: The residual magnetism existing in an electro-magnet suffices to develop an induced current in a rapidly revolving coil armature; this current, reacting upon the electro-magnet, determines the development of powerful magnetism in the latter by the inductive action of its insulated coils; the currents developed by the electro-magnet are consequently in their turn greatly increased in power, and react again upon the armature; and thus a great accumulation of electric force is very rapidly accomplished. When that accumulation has reached the maximum attainable without detriment to the insulation of the wire coils, a simple interrupting arrangement causes the current to be diverted from the machine to conducting wires, by whose medium it is utilized. The details of the machines vary according to the different plans adopted by the several constructors, but the above explanation applies more particularly to the earlier machines of Siemens and Halske, who were the first to produce a small instrument of this class thoroughly applicable to mining purposes, and almost equal in power to the ebonite frictional electric machine. Fifty Abel fuses, arranged in simple circuit, have been repeatedly exploded without any failures by one of these machines; it therefore provides with certainty the power necessary for the most extensive land or submarine mining operations, and is at the same time quite free from all disturbing atmospheric influences. Its mechanism is simple, and less easily susceptible of derangement than that of most magneto-electric apparatus; and as it is independent of everything but the application of manual power for the development of its action, it is far superior to the most perfect of these, independently of the fact that it surpasses them all greatly in power.

Various improvements have been introduced into these dynamo-electric exploders by Siemens Brothers, some at the instigation of the Royal Engineers Committee, at whose recommendation this instrument was adopted some years ago as the military service exploding machine. Other modifications of the dynamo-electric machine have recently been applied in forms suitable for use as a portable mine-exploder; a small description of Burgin's machine, and a very simple American ratchet machine, are among the most efficient of the dynamo-exploders now constructed.

The Siemens high-tension dynamo-electric machine now used in the Royal Engineer service, and which is not too heavy to be carried some distance by one man, is capable of firing between 120 and 150 Abel fuses in continuous circuit, and over 200 in two parallel circuits.

Although the phosphide of copper fuse was specially designed for use with generators of high-tension electricity, susceptible of advantageous employment as substitutes for voltaic batteries, its great sensitiveness to ignition rendered it equally available with voltaic piles, or batteries of high internal resistance; and this circumstance has exercised an important influence upon the rapid development of methods of applying electricity to important uses connected with naval offensive and defensive warfare.

It has been pointed out that magneto-electric instruments cannot be relied upon for submarine operations, on account of the very perfect insulation of the conducting wires, joints, &c., required to ensure success with them. On the other hand, frictional electric and dynamo-electric machines supply ample power for the simultaneous ignition of numerous submarine mines, even through cables in the insulation of which some defects exist. Hence, when any extensive submarine operation has to be accomplished, these machines may be used with advantage; but, for reasons to be pointed out presently, the frictional machine cannot be used as the exploding agent in connection with a system of submarine mines, of which it may be desired to explode any one particular mine, while leaving others in its vicinity intact. Dynamo-electric machines share this disadvantage with the frictional machines, when applied in conjunction with high-tension fuses. In addition to the special attention required by both these classes of machines, in localities where they might be

applied to submarine operations, there is one general objection to the use, in connection with naval and military operations, of any source of electricity, the development of which is entirely dependent upon manual operations to be performed at the instant an electric discharge is required; namely, that, however perfect all arrangements may be, their action at the last moment is still dependent upon individual vigilance and presence of mind. It need scarcely be stated that this objection would vanish in the case of dynamo-electric machines, if power were provided for working them continuously as long as any possibility existed of their being required.

The only sources of electricity which at present thoroughly fulfil the conditions essential in the exploding agent to be used with an efficient system of submarine mines, are constant voltaic batteries. By means of the high-tension fuse it became possible to use batteries which were previously inapplicable to the explosion of mines, because, even when employed in considerable numbers, the quantity of electricity furnished by them is not sufficient to effect the ignition of platinum wire-fuses. Thus, a number of elements of a Daniell's battery, or a sand battery, quite incapable of heating a platinum wire to redness, fires an Abel fuse with perfect certainty. The heat developed in the latter by the passage of a current from such a battery amply suffices to raise to its igniting point the readily explosive priming mixture, which serves as the conductor in the fuse. Moreover, the resistance presented by the fuse is so considerable, in comparison with that offered by the longest cables likely to be used in actual practice, that a current from a battery which possesses tension sufficient to overcome the resistance of the fuse, will explode the latter with as much certainty through cables of great length, as when it is close to the battery. A number of cells of a Bunsen battery, of sufficient power to ignite an Abel fuse, and also a fuse of platinum wire several inches long, when close to the battery, will no longer render even a very short piece of thin platinum wire moderately hot, if four or five hundred yards of ordinary conducting wire be placed in the circuit; while, on the other hand, its power to ignite an Abel fuse will not have become at all affected. It is evident from this illustration that the necessity for greatly adding to battery power, when mines are to be exploded through considerable lengths of wires, which existed with the use of the wire fuses, is obviated by employing a high-tension fuse; and thus one great objection to voltaic batteries, as exploding agents in mining operations, was set aside. Again, the sand batteries, or Daniell batteries, used for telegraphic purposes, which, when once charged, continue, with very little attention, in good working action for several months, could be substituted for the batteries (*e. g.* Grove's or Bunsen's) which it was formerly necessary to employ in order to attain sufficient quantity of current, and which continue in good action only for a few hours. Sand batteries have been repeatedly employed at Woolwich for the explosion of fuses after having been in action four or five months, with the occasional addition of a little water to compensate for evaporation.

It will be thus seen that constant voltaic batteries possess the essential qualifications of efficient exploding agents for use with any system of mines which it is desired to maintain for lengthened periods in a condition ready for explosion at any moment. They are simple of construction, comparatively inexpensive, require but little skill or labor for their arrangement or repair, and very little attention to keep them in constant good working order for long periods; and their action may be made quite independent of any operation to be performed at the last moment.

When first arrangements were devised for the application of electricity in our naval service to the firing of guns and to the explosion of so-called outrigger charges or mines, as originally used in boat attack in the American War, the voltaic pile recommended itself for its simplicity, the readiness with which it could be put together and kept in order by sailors, and the considerable power presented and maintained by it, with very fair constancy, for a number of hours. Different forms of pile were devised at Woolwich for boat and ship use, the

latter being of sufficient power to fire heavy broadsides by branch circuits, and to continue in a serviceable condition for twenty-four hours, when they could be replaced by fresh batteries, which had in the meantime been cleaned and built up by sailors. The pile for use in boats was of very portable form, and was enclosed in a suitably fitted box to protect it from the weather.

The Daniell and sand batteries first used, in conjunction with the phosphide fuse, in the earlier experiments for exploding submarine mines for purposes of defence, were speedily replaced by a modification of the battery known as Walker's, consisting of one zinc and two carbon plates immersed in dilute sulphuric acid. This battery was after some time converted into a modified form of the Leclanché battery, the packed carbon plate being surrounded by a U-shaped zinc plate.

The importance of being able to ascertain by direct electrical tests that the circuits leading to a mine, as well as the fuses introduced into that circuit for exploding the mine, are in proper order, became manifest when these applications of electricity were quite in their infancy. Many instances are on record in the earlier days of submarine mining of the disappointing results attending the accidental disturbance of electric firing arrangements, when proper means have not been known or provided for ascertaining whether the circuit is complete, or for localizing any defect when discovered. Thus, during one of the bombardments of Charleston, the United States ironclad "Ironsides" lay for several hours exactly over a large submarine mine containing 3000 lbs. of gunpowder, which had been placed with great care, but the explosion of which could not be effected, because, as was afterwards discovered, the conducting cable had been severed by the passage of a wagon over it.

It has been pointed out that testing arrangements were to some extent successfully applied in connection with the wire fuse in the earliest stages of its practical employment. It is scarcely necessary to state that the arrangements for testing all parts of a system of mines, especially in connection with submarine mines for defensive purposes, have some time since been carefully and completely elaborated.

The testing of the high-tension fuse, in which the bridge, or igniting and conducting composition, is composed of a mixture of the copper phosphide and sulphide with potassium chlorate, is easy of accomplishment (by means of feeble currents of high tension), in proportion as the sulphide of copper predominates over the phosphide. Even the most sensitive fuses, *i. e.* those containing the highest proportion of phosphide, may be thus tested without fear of exploding them; but when the necessity for a repeated application of tests, or even for the passing of an electric signal through the fuse, arises, as in the case of a permanent system of submarine mines, the case is different; for this particular fuse is susceptible of considerable alterations in conductivity on being frequently, or for long periods, submitted to even very feeble test-currents, and its accidental ignition, by passing through it such comparatively powerful test or signal currents as might have to be employed, becomes then so far possible as to create an uncertainty which is most undesirable.

For this reason, and also because the priming in these fuses is liable to some chemical change detrimental to its sensitiveness, unless thoroughly protected from access of moisture, another form of high-tension fuse, specially adapted for submarine mining service, was devised at Woolwich. This, though much less sensitive than the original Abel fuse, was quite sufficiently so for service requirements, while it presented great superiority over the latter in stability and uniformity of electric resistance; and though it was not altogether unaffected by the long-continued transmission of test currents through it, their action was not found to become detrimental to the efficiency of the fuse. This tension fuse was prepared by compressing a very intimate mixture of graphite and mercury fulminate into a cavity in which the terminals of the fuse very slightly projected; a feeble electric current was passed continuously through the fuse during the operation of pressing, a galvanometer and resistance coil

being in circuit, and the compression was continued until the desired resistance, or degree of conductivity, of the fuse was reached. To some comparatively small and variable extent, this conductivity fell gradually after the fuses had been manufactured; but, on the whole, a remarkable degree of uniformity was attained in their production.

In the employment of these fuses, which are always used in pairs in a mine, they are carefully selected and classed by testing before actual introduction into the mines.

Although high-tension fuses presented decided advantages in point of convenience and efficiency over the platinum wire fuse, as used in the earlier days of electrical firing, the requirements which arose in elaborating thoroughly efficient permanent systems of defence by submarine mines, and the demand for a form of battery for use in ships which would remain practically constant for long periods, and thus dispense with the necessity for frequent attention to the firing arrangements, caused a very careful consideration of the relative advantages of the high and low-tension systems of firing to result in favor of the employment of wire fuses for these services. The limits placed upon the amount of test or signal current which could be passed even through the least sensitive high-tension fuse, and the tendency of the latter to alter in conductivity when submitted to the action of those currents for long periods, were considerations decidedly in favor of the conclusion arrived at. In addition to these there was an element of uncertainty, or possible danger, in the employment of high-tension fuses, which, though in part eliminated by the employment of voltaic batteries in place of generators of high-tension electricity, might still occasionally constitute a source of danger, namely, the possible liability of high-tension fuses to be accidentally exploded by currents induced in cables, with which they were connected, during the occurrence of thunderstorms, or of less violent atmospheric disturbances.

It has been amply demonstrated by experiment, and by results obtained in military operations, that if insulated wires, immersed in water, buried in the earth, or even extended on the ground, are in sufficient proximity to one another, each cable being in circuit with a high-tension fuse and the earth, the explosion of any of the fuses by a charge from a Leyden jar or from a dynamo-electric machine of considerable power, may be attended with the simultaneous ignition of the fuses attached to adjacent cables, which are not connected with the source of electricity, but which become charged by the inductive action of the transmitted current to a sufficient extent to produce this result. Such being the case, it appears very possible that insulated cables extending to land or submarine mines, in which high-tension fuses are enclosed, may become charged inductively during violent atmospheric electrical disturbances to such an extent as to lead to the accidental explosion of such mines. Mr. Preece, in an interesting paper on underground telegraphs, which he contributed to the Society of Telegraph Engineers, gives an instance of the inductive effects of lightning discharges upon underground cables enclosed in pipes, the persons engaged in the operation of jointing the wires during a storm having seen sparks pass between the bare joint of the wires and the joint-box against which they were resting; and other eminent electricians confirmed, from personal experiences, that which he quoted. Although the lengths of cables used in mining operations are quite insignificant when compared with the shortest telegraph cables to which the observations of those gentlemen refer, the sensitiveness of high-tension fuses to ignition fully justified the doubts entertained whether their use might not be attended by a possibility of serious risk of accident, or at any rate of the unintentional explosion of mines placed in position for purposes of defence, especially in climates where very violent electrical disturbances are of frequent occurrence. Apprehensions of this nature were entertained by Von Ebner, and in a report by that officer on the defence of Venice, Pola, and Lissa, by submarine mines in 1866, he refers to the accidental explosion of one of a group of sixteen mines during a heavy thunder-

storm, as well as to the explosion of some mines in the harbor of Pola by the direct charging of the cables, through the firing station having been struck by lightning. It was to avoid such accidental explosions that he devised an ingenious but complicated circuit-closing arrangement, to be applied in the submarine mines themselves, by the employment of which the fuses in the mine were brought into connection with the cable leading to the firing stations only when the mine was struck by a passing ship.

Two instances of the accidental explosion of tension fuses by the direct charging of overhead wires during lightning discharges occurred in 1873 at Woolwich; and a fuse connected with an overhead insulated wire at Chatham was also exploded accidentally in the same year, though whether by an induced charge or by the direct action of a lightning discharge was not conclusively demonstrated. Subsequently, an electric cable was laid out at Woolwich along the river bank below low-water mark, and a tension fuse was attached to one extremity, the other being buried. About eleven months afterwards, the fuse was exploded by a charge induced in the conductor during a very heavy thunderstorm.

In consequence of the difficulties experienced in the special application of the high-tension fuses to submarine purposes, arising out of the circumstances just alluded to, the production of comparatively sensitive low-tension fuses, of much greater uniformity of resistance than those employed in former years, was made the subject of an elaborate experimental investigation by the lecturer, in the course of which several points of interest and of value in the subsequent application of the results were arrived at. Experiments instituted with platinum wires, much finer than those hitherto used in the construction of fuses, demonstrated that wires made of different specimens of commercial platinum varied very greatly in electrical conductivity. As these variations might be due to two causes, or combinations of them, namely, a difference in the purity and in the physical condition of the metal, the matter was investigated in both directions. It was found that very considerable differences in the amount of forging to which the metal, in the form of sponge, had been subjected, did not affect to any important extent either its specific gravity or its conductivity, and that the fused metal had only a very slightly higher degree of conductivity than the same sample forged from the sponge. It was therefore clearly established that the conductivity of such very fine wires as it was proposed to use in the construction of fuses was but slightly affected by physical peculiarities of the metal of which they were composed, and that the considerable differences in conductivity observed in different samples of platinum were ascribable to variations in the degree of purity of the metal. As it appeared likely, therefore, that more uniform results would be attained by the employment of some alloy of definite and uniform composition as the bridge for low-tension fuses than by the use of commercial platinum, varying considerably in composition, experiments were made with fine wires of German silver (which had been used by a well-known American electrician, Mr. Farmer, in the construction of comparatively sensitive wire fuses), and of the alloy of 66 of silver with 33 of platinum employed by Matthiessen for the reproduction of B. A. Standards of electrical resistance. It was found that both these alloys were greatly superior to ordinary platinum in regard to the resistance opposed to the passage of a current, and the heat consequently developed in given lengths of wire of a particular diameter, and that German silver was in its turn superior in this respect to the platinum silver alloy; although the difference was only trifling in the small lengths of fine wire used in a fuse (0.25 inch). On the other hand, the comparatively ready fusibility of a platinum-silver wire contributed, with other physical peculiarities of the two alloys, to reduce fine German silver wire to about a level with it. Moreover, German silver was found not to resist the tendency to corrosive action exhibited by gunpowder and other more sensitive explosive agents, which have to be placed in close contact with the wire-bridge in the construction of a fuse, so

that the latter may be at once fired when the required heat has been developed by the resistance which the wire-bridge offers to the current; platinum-silver, on the other hand, was found to remain unaltered under corresponding conditions of exposure.

The superiority of platinum-silver, and even German silver, as a material for the bridges of fuses, appeared, therefore, to be established from a practical point of view; but, as some difficulties were apprehended by the manufacturers in the uniform production of a silver alloy containing the large proportion of platinum essential to furnish the high-resistance wire required, experiments were made with alloys of platinum with definite proportions of iridium, the metal with which it is chiefly associated; and eventually very fine wires of an alloy containing 10 per cent. of iridium were selected as decidedly the best materials for the production of wire fuses of comparatively and very uniform high resistance, this alloy being found decidedly superior in the latter respect, as well as in point of strength (and therefore of manageableness in the state of very fine wire, 0.001 inch in diameter), to the platinum-silver wire. The fuses now used in military and submarine service are therefore made with bridges of iridio-platinum wire, containing 10 per cent. of the first-named metal; the wire-bridge in the fuses for submarine mining services, which are fired by means of Leclanché batteries, being somewhat thicker and therefore of higher conductivity than those used for land service, which are exploded by low-tension dynamo-electric machines manufactured by Siemens Brothers.

The electrical gun-tubes used in the navy are fired by means of a Leclanché battery specially devised for the purpose, and the circuits to the different guns are arranged in branch; when broadside firing is required, it is important that the wire-bridge of any one of the gun-tubes which is first fired should be instantaneously fused on the passage of the current, so as to cut this branch out of circuit; in this respect it was believed that the platinum-silver alloy, being much more fusible than iridio-platinum, presented an advantage, and hence the naval electrical fuses are made with bridges of that alloy; there is, however, no reason to believe that the finest wire of iridio-platinum is not quite as efficient for this particular service. Uniformity of electrical resistance has become a matter of such high importance in the delicate arrangements connected with our system of submarine mines, as now perfected, that the very greatest care is bestowed upon the manufacture of service electric fuses or detonators, which are in fact made, in all their details, with almost the precision bestowed upon delicate scientific instruments, and the successful production of which involved an attention to minutiæ which would surprise a superficial observer. Even the manner in which the wire-bridge had to be surrounded by a readily ignitable preparation to communicate fire to the charge of powder or mercury fulminate, in the fuse, involved much thought and experiment. The sensitiveness of the fuses as now manufactured is very uniform, while the manufacturing limits of variation in electrical resistance are very small.

It has been stated that the batteries used for exploding these sensitive wire fuses and detonators are varieties of the Leclanché, into which improvements have been introduced from time to time. It is very possible, now that dynamo-electric machines are applied to illuminating purposes in our large ships of war, and that the electric light is used for signalling and tactical purposes at the submarine mining stations of our naval ports, that the explosion of mines and the firing of guns by dynamo-electric agency may also be provided for, in time to come, as there would be no difficulty in providing the power for working these continuously, whenever they were likely to be called into use.

The applications of electricity to the explosion of gunpowder are so numerous and important that it is only possible, within the limits of this lecture, to give an outline of some of the more interesting and prominent.

One of the earliest of these was the firing of guns upon proof at Woolwich

by the voltaic battery, which was very efficiently carried out as far back as 1854 by Sergeant McKinlay, the proof-master, who employed a Grove battery and constructed a very neat gun-tube, which was fired by a platinum-wire bridge, surrounded by gunpowder in a small cup fixed on the top of the tube, the wire bridge being soldered to two small copper tubes or eyes, which passed through the cup and served to receive the terminals of the battery, an arrangement which was applied in various forms of electric tubes and fuses afterwards devised. The current was successively directed into the individual circuits connected with the guns to be proved at one time by means of a simple shunt-apparatus. Before the employment of this arrangement, the proof of guns was more than once attended by casualty, consequent upon the uncertain nature of the appliances which had to be adopted in firing the guns by means of a species of time-fuse. When the high-tension phosphide electric fuse had been devised, gun tubes were made to which it was applied, and after the proof operations had been carried out for some time by their means, with the use of Henley's large magneto-electric machine, an exploder was arranged by Wheatstone, which was provided with a large number of shunts, so that as many as twenty-four guns might be brought into connection with the instrument in rapid succession, and fired by the depression of separate keys connected with each. This method of firing has continued in use up to the present time, and Wheatstone's magneto-electric exploders have, moreover, performed good service at Woolwich and Shoeburyness during the last twenty-eight years, being used for the firing of guns, by means of the Abel gun-tubes, in all experiments connected with artillery, armor-plate and gunpowder investigations.

The firing of cannon as time-signals is an ancient practice in garrison towns, but the regulation of the time of firing the gun, by electrical agency from a distance, appears first to have been accomplished in Edinburgh, where, since 1861, the time-gun has been fired by a mechanical arrangement, actuated by a clock, the time of which is controlled electrically by the mean-time clock at the Royal Observatory on Calton Hill.

Shortly after the establishment of the Edinburgh time-gun, others were introduced at Newcastle, Sunderland, Shields, Glasgow, and Greenock. The firing of the gun was arranged for in various ways; in some instances it was effected either direct from the observatory at Edinburgh, or from shorter distances, by means of Wheatstone's magneto-electric exploders. Some of these guns were discontinued, but at the present time there are time-guns at West Hartlepool, Swansea, Tynemouth, Kendal, and Aldershot, which are fired electrically, either by currents direct from London, or by local batteries, which are thrown into circuit at the right moment by means of relays, controlled from St. Martins-le-Grand. The high-tension fuse, in the form of gun-tubes, is chiefly applied to these services.

It has already been pointed out, in tracing the successive changes in the nature of electric fuses, how, about thirteen years ago, the electrical firing of guns, especially for broadsides, was first introduced into the Navy, with the employment of the Abel high-tension gun-tube and voltaic piles. The gun-tubes, originally manufactured at the Woolwich Laboratory simply for the proof of cannon and for experimental artillery operations, and which were of very simple and cheap construction, were in the first instance adopted for use in the Navy, for the instantaneous firing of guns, and were obviously, as experience proved, unfitted to withstand exposure to the very various climatic influences which they had to encounter in Her Majesty's ships, and in store, in different parts of the world. They therefore were naturally found to deteriorate, and to have become unserviceable on several occasions, a result which was somewhat hastily ascribed entirely to the changeable nature of the priming composition with which these fuses were prepared. Unquestionably, however, the low-tension gun-tubes, having a bridge of very fine platinum-silver wire, surrounded by readily ignitable priming composition, are much more suited to our naval requirements than the comparatively very sensitive high-tension fuse.

The arrangements in Her Majesty's ships for firing broadsides electrically, and also for the electrical firing of guns in turret-ships, have been very carefully and successfully elaborated in every detail, including the provision of a so-called drill or dummy electrical gun-tube (which is used for practice and refitted by well-instructed sailors), the careful testing and balancing of the gun-tubes, examination of the gun-circuits, &c. ; and the guns may be fired either simultaneously from the conning tower on deck, or independently. For gun-firing, ships are supplied with a set of six very large Leclanché cells, arranged in series, a stout zinc plate being on either side of the packed carbon element, which is built of four gas-carbon plates attached to one common bridge. The ebonite trough, containing the plates, &c., measures 16 inches in length, and is 9 inches deep by 2¾ inches wide. The object of these large cells is to obtain a considerable quantity of electricity with as few elements as possible, thus reducing the loss of power which occurs when a large number of separate cells are connected up. The power of this battery-force is maintained for a long period in excess of the work it has to perform. A very portable arrangement of the Menotti form of Daniell battery, fitted with a galvanometer, is provided for testing batteries, &c., both for ship and boat service. The firing keys, and all other arrangements connected with electrical gun-firing, are specially designed to ensure safety and efficiency at the right moment.

The battery supplied for the firing of outrigger torpedoes, and for other operations to be performed from open boats, consists of a portable arrangement of three smaller cells of the Leclanché battery (the carbon element fitting into a U-shaped zinc plate) enclosed in a box, which is fitted externally with connecting screws, and a firing key, with safety arrangement to guard against its acting accidentally, and a strap to pass over the operator's shoulders, so that he has the instrument quite at his command in front of him. The electric detonators used with this battery correspond, so far as the bridge is concerned, with the naval electric gun-tubes.

These electric appliances are now distributed throughout the navy, and the men are kept, by instruction and periodical practice, well versed in their use.

The subject of the application of electricity to the explosion of submarine mines, for purposes of defence and attack, received some attention from the Russians during the Crimean War under the direction of Jacobi; thus a torpedo, arranged to be exploded electrically when coming into collision with a vessel, was discovered at Yeni-Kale, during the Kertsch expedition in 1855. Some arrangements were made by us, at the conclusion of the war, to apply electricity to the explosion of large powder charges enclosed in huge cylinders of boiler-plate, for the removal of sunken ships in Sevastopol Harbor, and of a large submarine obstruction of stone which the Russians had placed at the north entrance to Cronstadt Harbor; but they were not used. Torpedo defence, in its most simple form, was first applied by the Austrian Government in 1859, when a system of submarine mines, to be fired through the agency of electricity by operators on shore, was arranged by Von Ebner for the defence of Venice, which, however, never came into practical operation. Early in 1860, Henley's large magneto-electric machine, with a supply of Abel fuses, and stout india-rubber bags with fittings to resist water pressure, were dispatched to China, for use in the Peiho River, but no application appears to have been made of them. The subject of the utilization of electricity for purposes of defence did not, however, receive systematic investigation in England or other countries until some years afterwards, when the great importance of submarine mines as engines of war was demonstrated by the number of ships destroyed and injured during the war in America. Twenty-five vessels belonging to the Federal navy were destroyed, and nine others injured, by the explosion of mines and torpedoes, while the Confederates lost three vessels by accidentally coming into collision with their own mines, and one which was attacked by means of a torpedo and destroyed by the Federals. In only two of these cases of destruction, however, were the explosions accomplished by electrical agency;

in all the others, the mines were exploded by mechanical means. One instance of the effective power of a well-planned submarine mine may be selected from the experiences of the American Civil War, as an illustration of the formidable nature of this method of defence. The important defence of the water-approach to Richmond was entrusted to a single electric mine of considerable power, sunk in the channel-way of James River. This mine was under the control of an officer, who, stationed on one of the river banks, watched, from the sand-pit where he lay concealed, the approach of the enemy. A single stake planted upon the opposite bank served to indicate, by the passing vessel being on a line with his station and the stake, the exact moment when she would be within the area of destruction. With the patience of a spider watching for its victim, so for thirteen months did this officer remain, waiting for the opportunity to explode the mine with effect. At length the Federal fleet, under the command of Commodore Lee, entered the James River—the commodore's vessel being the third in the advancing rank. The foremost vessel, carrying seven guns, and manned with a picked crew of one hundred and twenty-seven men, was allowed to pass over the mine in safety (it being by arrangement held in reserve for the commodore's ship), when, the order having been passed from the deck of the next vessel, and audible on shore, for her to fall back and drag for torpedo-wires, the officer determined to explode his mine, and "hoist" her as she descended the stream. The explosion took place on a clear afternoon, and was witnessed by several persons; the hull of the vessel was visibly lifted out of the water, her boilers exploded, the smoke-stacks were carried away, and the crew projected into the air with great velocity; out of the hundred and twenty-seven men only three escaped alive. The awfully sudden and unexpected destruction of this vessel paralyzed the operations of the Federal fleet for a time, and Richmond was saved; Commodore Lee, declining to advance, sunk several of his ships, blocking up the channel way. This obstruction afterwards, on the advance of General Butler, gave rise to the cutting of the "Dutch Gap" canal, now a matter of history.

Soon after the commencement of that war, the attention of the English Government was called to the importance of practical inquiry into the value of submarine obstructions, both passive and active, as auxiliary agents of defence, and a Government Committee was appointed, in 1863, to report on the use which might be made of floating or sunken obstructions, and of submarine mines, in the defence of channels, harbors, and rivers. This Committee was enabled, by the aid of systematic investigations conducted for them at Woolwich during the following four years, by one of their members, Mr. Abel, and of practical experiments carried on chiefly at Chatham under the direction of another of their body, the late Colonel A. à'C. Fisher, C. B., R. E., to elaborate the subject of the application of electricity to submarine mines and torpedoes, to such an extent that a solid foundation of information was prepared for the several committees, appointed by the War Office and the Admiralty, who afterwards pursued different branches of the subject to the practical issues which were attained now some years since. It was towards the close of the labors of the so-called Floating Obstructions Committee (in 1867) that the School of Submarine Mining at Chatham, and the Naval Torpedo School at Portsmouth were developed, the foundation of the latter having been laid at the Chemical Department, Woolwich. Some continental governments also devoted attention to the subject of the application of electricity to submarine mines at about this time, and more especially the Austrian Government, for whom Baron von Ebner, who had already applied submarine mines to the defence of the harbor entrance of Malamocco in 1859, devised an ingenious and elaborate system of electric torpedo defence, for employment in conjunction with his high-tension fuses, which was applied to the defence of Venice, Pola, and Lissa, during the war of 1866, though its efficiency was not put to any actual test, except by way of experiment.

The application of electricity to the explosion of torpedoes was, as stated,

very limited during the American war; but arrangements for the extensive employment of that agent as the exploding power were far advanced in the hands of both the Federals and Confederates at the close of the war—men of very high qualifications, such as Captain Maury, Mr. N. J. Holmes, and Captain McEvoy, having worked arduously and successfully at the subject.

The explosion of submerged charges of gunpowder by mechanical contrivances, either of a self-acting nature or to be set into action at desired periods, was accomplished as far back as 1583, during the siege of Antwerp by the Duke of Parma. The English employed self-acting torpedoes against the French ships off Rochelle in 1628, and, from that period to 1854, devices of more or less ingenious and practicable character have been proposed from time time, and even applied, to some small extent, in different countries for the explosion of torpedoes either by clockwork at fixed periods, or by coming into collision with a ship. The Russians were the first to apply self-acting mechanical torpedoes with any prospect of success, and there is little doubt that, had the machines used for the defence of the Baltic been of larger size (they contained only 8 or 9 lbs. of gunpowder), their presence would have proved very disastrous to some of the English ships which came into collision with and exploded them. Various mechanical devices for effecting the explosion of torpedoes by their collision with a ship were employed by the Americans, a few of which proved very effective. But although, in point of simplicity and cost, a system of defence by means of mechanical torpedoes possesses decided advantages over any extensive arrangements for exploding submarine mines by electric agency, their employment is attended by such considerable risk of accident to those at whose hands they receive application that, under many circumstances which are likely to occur, they become almost as great a source of danger to friend as to foe. Thus, the operations of lowering and mooring the mine, the explosion of which depends upon the application of a blow, thrust, or pull to some portion of the machine, which is so placed and arranged as to be in a favorable position for the application of mechanical action by a passing ship, are attended with very great danger to those employed, unless some means are adopted for rendering the exploding mechanism inactive until after the torpedo has been placed in position. But the employment of a safeguard of this kind involves a considerable amount of uncertainty as to the torpedo being rendered active after the operation of mooring is completed, because the very removal of the safeguard is frequently a dangerous operation. Again, when once self-acting mechanical mines have been placed in position and rendered active, they are as dangerous to friendly ships as to the enemy; consequently their employment for the defence of a particular tract of water completely closes it until they have been exploded or removed, and their removal obviously constitutes one of the most dangerous services on which men can be employed. Several instances occurred in America, some years after the termination of the war, of the destruction of ships in waters which had been defended by mechanical mines, the subsequent removal of which was thought to have been completely accomplished. Some improvements have recently been made in mechanical and chemical appliances of a self-acting nature for submarine mines, by the employment of which the mooring arrangements can be completed in perfect safety, and the torpedoes afterwards rendered active, by the performance of a simple and perfectly safe operation, when it is desired to close the defended water. But the complete exclusion of friendly vessels, and the difficulties attending the raising of self-acting mechanical mines when no longer required, still constitute formidable objections against their use, excepting in the case of tracts of water which are not ordinarily navigated, but the passage of which in time of war might be attempted by vessels of light draught. The most successful result yet obtained in this direction has been by a combination of mechanical with self-contained electrical arrangements which have been devised by Mr. Matheson and others.

The most important advantages secured by the application of electricity as

an exploding agent of submarine mines are as follows: they may be placed in position with absolute safety to the operators, and rendered active or passive at any moment from the shore; the waters which they are employed to defend are therefore never closed to friendly vessels until immediately before the approach of an enemy; they can be fixed at any depth beneath the surface (while mechanical torpedoes must be situated directly or nearly in the path of a passing ship), a circumstance which very considerably simplifies the arrangements for their application in tidal waters; lastly, electric mines may, when no longer required, be removed with as much safety as attended their application.

There are two distinct systems of applying electricity to the explosion of submarine mines. The most simple is that in which the explosion is made dependent upon the completion of the electric circuit by operators stationed at one or more posts of observation on shore. The particular mode of arrangement, and the operation to be adopted, depend in great measure on the nature of the locality to be defended. If this be a river or channel the plan of arranging and exploding mines is comparatively simple, but will serve sufficiently to illustrate the general nature of this system of applying torpedoes. The mines are arranged across the river or channel in rows or lines, converging towards a station on shore to which the conducting cables are led which are to connect each mine with the exploding instrument. The operator at this station has it in his power, therefore, to explode any one of the mines at will, by completion of the circuit through the particular cable and the earth. Some other position on shore is selected as a second station, which commands points of view intersecting the lines of mines. The operators at the two stations are placed in telegraphic communication with each other, and when a ship is observed by the operator at the second station to approach in the direction of any one of the mines, he will signal to the man who looks along this line, and the latter will complete circuit as soon as the vessel appears over the particular mine specified. Should the vessel alter her course in approaching the mine, the operator at the observing station will inform the man at the firing station, who will alter his arrangements accordingly. Or the man at the observing station, when he perceives a vessel to approach in a line with any of the mines, places the cable of that mine in electric connection with the operator at the other station, and the latter will complete the circuit through the earth as soon as he sees that the vessel is over the first line of mines. Other more or less elaborate modifications of these modes of observing and exploding have been proposed; they all depend for efficiency on the experience, harmonious action, and constant vigilance of the operators at the exploding and observing stations. They are, moreover, entirely useless at night, and in any but clear weather. Mines arranged solely for firing by observation are therefore not to be compared in general efficiency to self-acting mines, which are either exploded by their collision with a ship, whereby electric circuit is completed within them, or by the vessel striking a circuit-closing arrangement moored near the surface of the water, whereupon either the mine, moored at some depth beneath, is instantly exploded, or a signal is furnished at the station on shore which indicates to an operator the particular mine to be exploded. The object to be attained in these circuit-closing apparatus, which are so moored as to be within range of a passing ship, is to oppose in the path of a vessel a contrivance which will not be affected by the motion of the water, but which will complete electric circuit between the conducting cable and the fuse, or will bring a relay into operation which throws the fuse into circuit with the firing battery if the circuit closer be struck in some particular part, or thrown into a particular position by the advancing ship. Many ingenious contrivances have been devised for this purpose and experimented with, but only a few have furnished satisfactory results, the conditions essential to success being numerous, and their combined fulfilment not easy of attainment. Simplicity of mechanism, and a combination of sufficient, but not excessive, delicacy of action, with permanence during long immersion, are among the most important objects to be

aimed at in the construction of these circuit-closing or signalling machines, or self-acting mines.

One of the earliest circuit-closers with which any measure of success was obtained was devised by the lecturer in 1864, and extensively experimented with by successive Committees at Chatham; though efficient of its class it was decidedly inferior to circuit-closers of which the entire mechanism is enclosed and therefore protected from injury. Of this class the first really efficient one was that devised by Mr. Matheson (late Quartermaster-Sergeant, R. E.), which was adopted into the service some years ago, and was gradually modified and improved until the present English service circuit-closer was produced.

Such are the general principles of the arrangements adopted in connection with the application of electricity to the explosion of submarine mines; it would be beyond the scope of this lecture to enter into details respecting the numerous arrangements and appliances connected with a system of defence by submarine mines, such as is now ready for application at any time at our several naval ports at home and abroad, and the utilization of which has already been actively taken up by our colonies.

Continental nations have followed in our footsteps, in providing themselves with equipments for defensive purposes by submarine mines, and our Scandinavian friends, the Danes, Swedes, and Norwegians, have pursued the subject of submarine mines with special activity and success. Experiments, vying with our own in extent and importance, have been instituted by them on the effects of submarine explosions, and the relative merits of different systems of mines and auxiliary arrangements, some very simple and efficient circuit-closers and other appliances having been elaborated by them.

In England, while we are fortunate in having eminent electric engineers and mechanicians like Captain McEvoy and Mr. Matheson, always active in developing improvements in the science of submarine warfare, our corps of Royal Engineers must be congratulated upon the unceasing activity and success with which many of their most talented officers have labored at the continual improvement of our armament for submarine mining service, and upon the zeal with which they endeavor to make every important advance in applied electrical science contribute to increase the completeness of our arrangements for submarine electric operations of defence and offence, and of our control over those arrangements. That endeavors are made to utilize in this direction every important advance in electrical science and in the practical results emanating therefrom, is illustrated by the important uses already made of the electric light in connection with submarine mining service, and by promising results obtained in the application of accumulative batteries as the signaling batteries for mines; in the employment of the microphone for detecting the approach of ships to a submarine mine station; in the use of Hughes' induction balance as a means of searching for submerged mines, &c.

In the United States, where the first great impetus was given to the utilization of electricity as an exploding agent for war purposes, the subject has continued to be actively pursued, and important improvements in exploding instruments, electric fuses, and other appliances, have been made from time to time by Smith, Farmer, Hill, Striedinger, and others already mentioned. But no individual has contributed more importantly to the development of the service of submarine explosions than General Abbot, of the United States Engineers. That officer has been for years past engaged upon valuable work connected with the application of electricity to explosions, and the scientific and practical elaboration of the conditions to be fulfilled in the successful accomplishment of simultaneous explosions upon a large scale; the value of the work performed by him in this direction was demonstrated by the remarkable success of by far the most gigantic operation of electric explosion which has been accomplished, to which further reference will presently be made. In an official report upon investigations to develop a system of submarine mines for defending the harbors of the United States, printed in 1881, General Abbot

includes an account of a most valuable series of experimental and theoretical investigations of the physical phenomena and force developed by submarine explosions with all the most prominent explosive mixtures and compounds, and of the properties and relative merits of the various high, medium, and low tension fuses, and of every class of electrical igniting apparatus. This work is rich in original and important observations and deductions, and well illustrates the very comprehensive nature of the science of submarine mining.

Illustrations of actual results capable of being produced in warfare, by the application of electricity to submarine operations, have hitherto been very few, but of the moral effects of submarine mines we have already had abundant proof. In the war which was carried on for six years by the Republics of Brazil and of Uruguay and the Argentine Republic of Paraguay, the latter managed, by means of submarine mines, to keep at bay for the whole period the Brazilian fleet of fifteen ironclads and sixty other men-of-war. The means available for applying electricity to the explosion of these mines were limited; a large proportion of the three hundred that were laid down were therefore arranged for explosion by mechanical means. In the Russo-Turkish war, submarine mines and torpedoes were a source of continued apprehension, and it is well known that the French naval superiority was paralyzed, during the Franco-German war, by the existence, or reputed existence, of mines in the Danube.

The application of electricity to the explosion of military mines, and to the demolition of works and buildings, from a safe distance, has, it need hardly be stated, been of great importance in recent wars in expediting and facilitating the work of the military engineer. The rapidity with which guns, carriages, &c., were disabled and destroyed by a small party of men who landed after the silencing of the forts at Alexandria, furnished an excellent illustration of the advantages of electrical exploding arrangements, combined with the great facility afforded for rapid operation by the power possessed of developing the most violent action of gun-cotton, dynamite, &c., through the agency of a detonation, without any necessity for confining or tamping the charge.

The application of electricity to the explosion of mines for land defences during active war is by no means an easy operation, inasmuch as not only the preparation of the mines, but also the concealment of electric cables and all appliances from the enemy, entails great difficulties, unless circumstances have permitted, or have appeared to render it prudent to make, the necessary arrangements in ample time to prevent a knowledge of them reaching the enemy. An elaborate system had been elaborated for defending the chief approaches to Paris in this way in 1870, but no preparations were attempted until it was impracticable to render this system of defence available.

Turning from military and naval applications of electricity to explosive purposes, but few words need be said to recall to the minds of civil engineers the facilities which the employment of electricity as an exploding agent affords for expediting the carrying out of many kinds of work in which they are immediately interested. Electrical blasting, especially when used in combination with rock-boring machines, has revolutionized the operations of tunnelling and driving of galleries; and, although in ordinary mining and quarrying operations, the additional cost involved in the employment of fuses and conductors, and the original price of the exploding machine, are not unfrequently of serious consideration, there are, even in those directions, many occasions when the power of firing a number of shots simultaneously is of very great importance. There is little doubt, moreover, that accidents in mining and quarrying would be considerably reduced in number if electrical blasting were more frequently employed, especially in dangerous mines, instead of the comparatively uncertain system of firing by slow-burning fuse. Many men meet their doom through going up to a shot hole in the false belief that the fuse has burned out or become extinguished. With electric firing the simplest precautions suffice to ensure absolute safety.

A substitute for electrical firing, which possesses considerable merit, and which has been applied with success to the practically simultaneous firing of several charges, claims a passing notice here. It is a simple modification of the Bickford fuse, which, instead of burning slowly, flashes rapidly into flame throughout its length, and hence has received the name of instantaneous fuse, the earliest form having been brought from America under the name of lightning fuse. The fuse, as manufactured by Messrs. Bickford, Smith & Co., burns at the rate of about 100 feet per second; it has the general external characteristics and flexibility of the ordinary mining fuse, but is distinguished from the latter by a colored external coating. Numerous lengths of this fuse can be coupled up together in a simple manner, so as to form branches leading to different mines or shot holes, which may be ignited together, so as to fire the holes almost simultaneously. In the navy this fuse is used as a means of firing small gun-cotton charges which may be thrown by hand into boats when these engage each other, the fuse being fired from the attacking boat by means of a small pistol, into the barrel of which the extremity is inserted. In hurried attacks of this nature it would be difficult to deal with wires and electrical exploders.

The conveniences presented by electric-firing arrangements, under special circumstances, are interestingly illustrated by a novel proceeding at the launch of a large screw steamer at Kinghorn, in Scotland, about a year ago. This launch was accomplished by placing small charges of dynamite in the wedge blocks along the sides of the keel, and exploding them in pairs, one on each side of the vessel, hydraulic power being applied at the moment that the last wedges were shot away.

In the deepening of harbors and rivers, and the removal of natural or artificial submerged obstructions, the advantages of electric-firing are so obvious that it is only necessary to refer to them; but this account of the application of electricity as an exploding agent cannot be better concluded than by a brief recital of the most extensive operation of the above kind which has hitherto been carried out, namely, the destruction of the reef of Hallett's Point (Hell Gate) in East River, New York, in September, 1876. The area of rock operated upon, which included all that portion of the reef within the curve of 26 feet below mean low water, was 3 acres. This space was perforated with forty-one radial tunnels, long and short, and with eleven transverse galleries, leaving as supports to the roof one hundred and seventy-two piers. The aggregate length of tunnels and galleries was 742,567 feet; the amount of rock which had been excavated from these was 49,480 cubic yards; and the time consumed in this work was four years and four months. The work of drilling charge-holes was commenced in June, 1875, and at its completion, in March, 1876, five thousand three hundred and seventy-five 3-inch holes had been drilled in the roofs, and in the piers one thousand and eighty 3-inch, and two hundred and eighty-six 2-inch holes; the total length of holes drilled being 58,445 feet. In the earlier portion of the work of excavation, powder was used for blasting, but from June, 1872, machine-drills and violent explosives were gradually brought into use. Dittmarr's preparation of nitrated sawdust and nitro-glycerine, known as dualin, and nitro-glycerine alone, manufactured by Mr. Mowbray, were employed experimentally in the earlier operations. In the concluding demolition the explosives used were giant powder, or No. 1 dynamite; rendrock (the name adopted in America for litho-fracteur); and Vulcan powder, or Vigorite, another nitro-glycerine preparation, which is a mixture of nitrate of soda, sulphur, and charcoal, with about 30 per cent. of nitro-glycerine. A total of 49,914 pounds of these explosives was used in the single operation. The number of holes charged with these was four thousand four hundred and twenty-seven. The operation of charging occupied nine days. The detonating electric fuses, charged with mercury fulminate, were contained in priming charges weighing ¾ pound each, enclosed in brass tubes; these were inserted over the charges, which were enclosed in tin cases hermetically closed to ex-

clude access of water. Very simple and effectual means were used for fixing the cases in the holes in the roofs of the galleries, &c. The charges were connected in continuous series in groups of twenty, and these again were arranged in divided circuit in eight groups, every group being connected with a distinct carbon zinc battery of forty to forty-four cells. Each battery was thus arranged to explode one hundred and sixty charges. The simultaneous explosion of the complete system of mines was accomplished by a simple circuit-closer, governing the whole of the twenty-three series of charges, which was devised by Julius Striedinger, C. E., who rendered important services in connection with the electrical arrangements.

All was completed by the 23d of September, 1876. Water was admitted to the excavations, which were filled to the level of the tide in seven and a half hours, and the simultaneous explosion of the charges was effected on the following day. The maximum height to which spray was projected by the explosion was 123 feet, the volume of water raised being comparatively trifling, as was also the shock of the explosion. Advantage was taken of this stupendous operation to make observations on the rate of transmission through the earth's crust of an artificially produced impulse analogous to an earthquake ; and this work was entrusted to General Abbot, who worked out the formulæ regulating the arrangements of the batteries, fuses, and circuits by which the operations were brought to a successful issue. The total amount of rock demolished by the explosion was 63,135 cubic yards. As an illustration of the electric simultaneous explosion of charges, this operation still remains without a parallel, and, though it was obviously impossible to ascertain whether the whole, or what proportion, of the charges had exploded, there appears little doubt, from the completeness of the demolition, that the operation was practically successful over the whole area operated upon. Mr. Striedinger's circuit-closer consisted simply, on the one hand, of a fixed wooden plate or slab fitted with a number of mercury-cups corresponding to the number of firing circuits, one of the wires from each of which being attached to the cups below the plate that supported them ; and, on the other hand, of a similar movable plate placed vertically over the fixed plate, and carrying a number of brass pins, corresponding to the mercury cups, and connected with the other branches of the circuit. The latter plate was suspended immediately over the fixed one by a cord, into which a small cartridge was introduced ; the explosion of this by an independent battery severed the cord, and allowed the pins to enter the mercury-cups simultaneously.

The outline which has been given of this branch of applied electricity, though unavoidably superficial, will, it is hoped, have conveyed some idea of its history, development, and importance, and have also in some measure served to substantiate its claim to rank, if only the last, among the great illustrations which have been brought before you in this course, of the practical benefits resulting from the patient study of science.

ON THE TENSION OF WINDING WIRE GUNS.

By Ensign Philip R. Alger, U. S. N.

If wire be wound upon a tube, the inner layers will evidently be more and more relieved of tensile strain as the winding proceeds, in consequence of the compressive force exercised by the outer layers, and, on the completion of the winding, the inner layer will be at a considerably less, and the outer layer at the same tension as that of winding. Consequently, when an internal pressure is applied, the exterior layers of wire will first be brought to a higher tension than that at which they were wound, and, if the tension of winding be high, will also first be strained beyond the elastic limit and permanently stretched.

In order, then, that the application of an internal pressure may strain the layers of wire uniformly, it is necessary that the exterior layers be wound at a less tension than the interior layers, and the object of this investigation is the determination of the proper tension of winding each layer.

We will consider the case of a simple tube wound with wire. We wish to determine the thickness of the tube, the number of layers of wire, and the tension of winding each layer, so that under a given internal pressure all the layers of wire shall be equally strained and the tube shall have a given tension, and, at the same time, so that when the gun is at rest the compression of its bore shall not exceed a given amount.

Let $R_0 =$ radius of bore.
$R_1 =$ outer radius of tube.
$R_2 =$ outer radius of wire.
$P_0 =$ maximum powder pressure.
$T_0 =$ limit of tension of tube under strain.
$T =$ limit of tension of wire under strain.
$C_0 =$ limit of compression of tube at rest.
$E_0 =$ modulus of elasticity of tube.
$E_1 =$ modulus of elasticity of wire.

Suppose the wire wound upon the tube in the proper manner, and the structure in equilibrium under an internal pressure P_0, the inner surface of the tube having a tension T_0, and each layer of wire a tension T. At a point of radius r in the mass of wire the existing tension T is the combination of three strains—that of winding, that caused by the internal pressure, and that caused by the compressive force of the layers of wire outside it. The tension of each layer of wire being T, the radial pressure caused by the layers outside the point of radius r is evidently $\left(\frac{R_2 - r}{r}\right) T$, and, if we remove these layers, and apply in their place a radial pressure $\left(\frac{R_2 - r}{r}\right) T$, the structure will still be in equilibrium, the tension at r remaining unchanged. Now if we cause the internal pressure P_0 and the external pressure $\left(\frac{R_2 - r}{r}\right) T$ to vanish, evidently the wire at r will assume the tension at which it was wound, and then, if we find the change of tension at r caused by this removal of pressures, and apply this change to the tension T, the result will be the required tension of winding at radius r.

If the state of equilibrium of the structure is modified in any way, let

$p_0 =$ resulting change of pressure at R_0,
$p_1 =$ resulting change of pressure at R_1,
$p_2 =$ resulting change of pressure at r,
$t_0 =$ resulting change of tension of inner surface of tube.
$t'_0 =$ resulting change of tension of outer surface of tube.
$t_1 =$ resulting change of tension of inner layer of wire.
$t'_1 =$ resulting change of tension of outer layer of wire.

We then have the following equations, given in Virgile's "Resistance of Metallic Tubes," and easily deduced from the equations of equilibrium of a homogeneous elastic tube:

$$(1) \qquad p_2 = -t_1 \frac{r^2 - R_1^2}{2r^2} + p_1 \frac{r^2 + R_1^2}{2r^2},$$

$$(2) \qquad p_1 = -t_0 \frac{R_1^2 - R_0^2}{2R_1^2} + p_0 \frac{R_1^2 + R_0^2}{2R_1^2},$$

$$(3) \qquad t'_0 = t_0 \frac{R_1^2 + R_0^2}{2R_1^2} - p_0 \frac{R_1^2 - R_0^2}{2R_1^2},$$

$$(4) \qquad t_1 = \frac{E_1}{E_0}\left(t'_0 + \frac{p_1}{3}\right) - \frac{p_1}{3},$$

$$(5) \qquad t'_1 = t_1 \frac{r^2 + R_1^2}{2r^2} - p_1 \frac{r^2 - R_1^2}{2r^2}.$$

Combining (1) with (2), and (4) with (2) and (3), we have

$$(6) \qquad p_2 = -t_1 \frac{r^2 - R_1^2}{2r^2} - \frac{r^2 + R_1^2}{2r^2}\left(t_0 \frac{R_1^2 - R_0^2}{2R_1^2} - p_0 \frac{R_1^2 + R_0^2}{2R_1^2}\right), \text{ and}$$

$$(7) \qquad t_1 = \frac{E_1}{E_0}\left[\frac{t_0}{3}. \frac{R_1^2\left(2 + \frac{E_0}{E_1}\right) + R_0^2\left(4 - \frac{E_0}{E_1}\right)}{2R_1^2} - \frac{p_0}{3}. \frac{R_1^2\left(2 + \frac{E_0}{E_1}\right) - R_0^2\left(4 - \frac{E_0}{E_1}\right)}{2R_1^2}\right]$$

Eliminating t_0, we have

$$(8) \qquad t_1 = \frac{3R_0^2 p_0 (r^2 + R_1^2) - r^2 p_2 \left[R_1^2\left(2 + \frac{E_0}{E_1}\right) + R_0^2\left(4 - \frac{E_0}{E_1}\right)\right]}{r^2\left[2R_0^2\left(1 - \frac{E_0}{E_1}\right) + R_1^2\left(1 + 2\frac{E_0}{E_1}\right)\right] - R_1^2\left[R_0^2\left(2 + \frac{E_0}{E_1}\right) + R_1^2\left(1 - \frac{E_0}{E_1}\right)\right]}$$

To simplify (8), let $\quad a = 1 - \frac{E_0}{E_1}$,

$$b = 1 + 2\frac{E_0}{E_1}, \quad A = 2aR_0^2 + bR_1^2,$$

$$c = 2 + \frac{E_0}{E_1}, \quad B = cR_0^2 R_1^2 + aR_1^4,$$

and we have

$$(9) \qquad t_1 = \frac{3p_0 R_0^2 (r^2 + R_1^2) - p_2 r^2 (cR_1^2 + aR_0^2 + 3R_0^2)}{Ar^2 - B},$$

also combining (1) with (5), we have

$$(10) \qquad t'_1 = t_1 \frac{2R_1^2}{r^2 + R_1^2} - p_2 \frac{r^2 - R_1^2}{r^2 + R_1^2}.$$

Now, eliminating t_1, we have, after reduction,

$$(11) \qquad t'_1 = \frac{6p_0 R_0^2 R_1^2 - p_2 (Ar^2 + B)}{Ar^2 - B}.$$

In other words, if the internal and external pressures undergo variations p_0 and p_2, the tension at the outer surface of the wire will undergo a variation t'_1, given by equation (11); hence, in (11) putting $p_0 = -P_0$ and $p_2 = -\left(\frac{R_2 - r}{r}\right) T$, we have

$$t'_1 = \frac{T\left(\frac{R_2 - r}{r}\right)(Ar^2 + B) - 6P_0 R_0^2 R_1^2}{Ar^2 - B},$$

and $T + t'_1$ equals the required tension of winding at radius r.

$$(12) \qquad T + t'_1 = t_r = \frac{\frac{TR_2}{r}(Ar^2 + B) - 2BT - 6P_0 R_0^2 R_1^2}{Ar^2 - B}.$$

We have now to determine the compression of bore caused by winding wire at the tension given above.

Suppose the winding to have proceeded to a radius r; we wish to find the change of tension of the bore caused by the application of a new layer of wire at the tension t_r.

In (7) and (9) let $p_0 = 0$ and we have,

$$(13) \qquad t_1 = \frac{E_1}{E_0}\left[\frac{t_0}{3} \cdot \frac{cR_1^2 + aR_0^2 + 3R_0^2}{2R_1^2}\right] \text{ and}$$

$$(14) \qquad t_1 = -p_2 r^2 \left[\frac{cR_1^2 + aR_0^2 + 3R_0^2}{Ar^2 - B}\right].$$

Eliminating t_1 and reducing, we have

$$(15) \qquad t_0 = -6R_1^2 \frac{E_0}{E_1} p_2 \frac{r^2}{Ar^2 - B}.$$

Now in (15) let $p_2 = \frac{t_r dr}{r}$, the radial pressure caused by a single layer of wire, and we have for the total compression of bore caused by winding to a radius R_2,

$$(16) \qquad C_0 = 6R_1^2 \frac{E_0}{E_1} \int_{R_2}^{R_1} \frac{p_2 r^2 dr}{Ar^2 - B} = 6R_1^2 \frac{E_0}{E_1} \int_{R_2}^{R_1} \frac{rt_r dr}{Ar^2 - B} =$$

$$6R_1^2 \frac{E_0}{E_1} \int_{R_2}^{R_1} \frac{TR_2(Ar^2 + B) - r(2BT + 6P_0 R_0^2 R_1^2)}{(Ar^2 - B)^2} dr =$$

$$6R_1^2 \frac{E_0}{E_1} \cdot \left[\frac{ABT + 3AP_0 R_0^2 R_1^2 - A^2 TR_2 r}{Ar^2 - B}\right]_{R_2}^{R_1} =$$

$$\frac{6R_1^2 \frac{E_0}{E_1}(R_2 - R_1)}{AR_1^2 - B}\left[T - \frac{3P_0 R_0^2 R_1 (R_2 + R_1)}{AR_2^2 - B}\right] =$$

$$\frac{2R_1(R_2 - R_1)}{R_1^2 - R_0^2}\left[T - \frac{3P_0 R_0^2 R_1 (R_2 + R_1)}{AR_2^2 - B}\right]$$

These two equations (12) and (16) furnish the means of determining the proper tension of winding at any point and the compression of bore when the gun is at rest after winding.

We have next to determine the thickness of tube necessary to fulfil the given conditions.

When the internal pressure P_0 acts, the pressure on the external surface of the tube is evidently $\left(\frac{R_2 - R_1}{R_1}\right) T$, and we have, therefore, for the pressure that will strain the tube to a tension T_0,

$$(17) \qquad P_0 = \frac{R_1^2 - R_0^2}{R_1^2 + R_0^2}\left(T_0 + \left(\frac{R_2 - R_1}{R_1}\right) T\right) + \left(\frac{R_2 - R_1}{R_1}\right) T.$$

From these three equations, (12), (16) and (17), having R_0, P_0, T_0, C_0, and T, we are enabled to find R_1, R_2, and t_r, or the thickness of the tube, the number of layers of wire, and the tension of winding each layer.

In deducing these formulæ, one doubtful assumption has been made, the longitudinal tension has been neglected, or assumed to be uniformly distributed over the whole cross section of the tube. This is not strictly true, but it is, in all probability, so nearly true that its assumption will have no material effect upon results.

In general practice the breech plug is housed in a jacket placed over an inner tube in order to lessen the size of the forgings used and to obviate the bad effects of the expansion of the bore upon the first threads of the screw box. This will have no effect upon our results, however, for, having obtained the thickness of the tube, it may be divided into two parts, the outer of sufficient cross section to take all longitudinal strain.

Almost always the tube will be of the same material as the wire—steel; in which case we have $E_0 = E_1$, and (12) and (16) reduce to

$$t_r = \frac{TR_2}{r} + \frac{2R_0^2}{r^2 - R_0^2}\left(\frac{TR_2}{r} - T - P_0\right) \text{ and} \tag{18}$$

$$C_0 = \frac{2(R_2^2 - R_1^2)}{R_1^2 - R_0^2}\left(\frac{R_1 T}{R_2 + R_1} - \frac{P_0 R_0^2}{R_2^2 - R_0^2}\right). \tag{19}$$

In this case, also, we can find direct values of R_1 and R_2, for, combining (17) and (19), we have, after reduction,

$$R_2 = R_0\sqrt{\frac{T_0 + C_0 + P_0}{T_0 + C_0 - P_0}} \text{ and} \tag{20}$$

$$R_1 = \frac{TR_2 + \sqrt{TR_2^2 - R_0^2(P_0 + T_0)(P_0 - T_0 + 2T)}}{P_0 - T_0 + 2T} \tag{21}$$

Equation (20) shows, what must always be the case in a gun built of one material, that the strength depends directly upon the range of extension of the inner surface of the tube from extreme compression to extreme tension, and can never exceed the sum of the elastic limits of compression and extension.

The working of the formulæ deduced above is best shown by an example. We will assume the radius of the chamber of an all steel gun to be 7″, the elastic limit of the metal of tube and jacket to be 18 tons, and the elastic limit of the wire to be 36 tons; we wish a construction having an elastic strength of 27 tons.

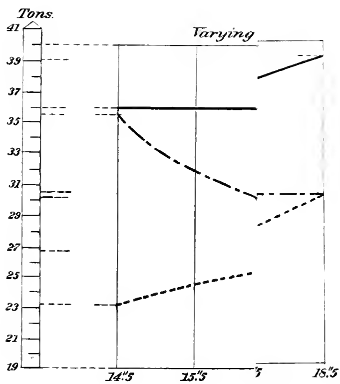
$R_0 = 7.$
$T_0 = C_0 = 18$ tons.
$T = 36$ "
$P_0 = 27$ "

To obtain R_2 and R_1 we have

$$R_2 = R_0\sqrt{\frac{T_0 + C_0 + P_0}{T_0 + C_0 - P_0}} = 7\sqrt{\frac{63}{9}} = 7\sqrt{7} = 18.5'',$$

$$R_1 = \frac{TR_2 + \sqrt{T^2R_2^2 - R_0^2(P_0 + T_0)(P_0 - T_0 + 2T)}}{P_0 - T_0 + 2T} = 14.5''.$$

The tube, therefore, must be 7.5″ thick, and, to secure a safe longitudinal strength, this may be divided into two parts, the inner, or tube proper, 3.5″ thick, and the outer, or jacket, in which the plug houses, 4.5″ thick.


Tons.
41
39
37
35
33
31
29
27
25
23
21
19
Varying
14."5
15."5
18."5

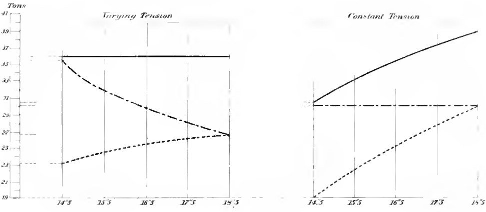
Now substituting in (18) the value of R_2 found and the given values of T, R_0, and P_0, $t_r = \frac{666}{r} + \frac{98}{r^2-49}\left(\frac{666}{r} - 63\right)$, which gives the tension of winding as follows:

$r = 14.5''$ $t_r = 35.4$ tons.
$r = 15.5''$ $t_r = 32.6$ "
$r = 16.5''$ $t_r = 30.3$ "
$r = 17.5''$ $t_r = 28.5$ "
$r = 18.5''$ $t_r = 26.9$ "

To test our results we will substitute the values of R_2 and R_1 in (19); we have $C_0 = \frac{264.0}{161.25}\left(\frac{522}{33} - \frac{1323}{293.25}\right) = 18$ tons, the value assumed.

To illustrate the different strains produced by winding wire at a constant and at a decreasing tension, the following diagrams are given. In the first the *dash* line shows the constant tension of winding (just sufficient to compress the metal of the bore to its elastic limit, 18 tons), the *dotted* line shows the state of strain of the wire after winding, and the full line that under an internal pressure of 27 tons. In the second the *dash* line shows the varying tension of winding, the dotted line the state of strain after winding, and the full line the state of strain under an internal pressure of 27 tons.

It will be seen that in the first case the pressure of 27 tons strains the outer layers of wire beyond the elastic limit of 36 tons, while in the second case no part of the wire passes the limiting tension.


Tons
Varying Tension
Constant Tension
41
39
37
35
33
31
29
27
25
23
21
19
14°5
15°5
16°5
17°5
18°5

Now substituting in (18) the value of R_2 found and the given values of T, R_0, and P_0, $t_r = \frac{666}{r} + \frac{98}{r^2 - 49}\left(\frac{666}{r} - 63\right)$, which gives the tension of winding as follows:

$r = 14.5''$	$t_r = 35.4$ tons.
$r = 15.5''$	$t_r = 32.6$ "
$r = 16.5''$	$t_r = 30.3$ "
$r = 17.5''$	$t_r = 28.5$ "
$r = 18.5''$	$t_r = 26.9$ "

To test our results we will substitute the values of R_2 and R_1 in (19); we have $C_0 = \frac{264.0}{161.25}\left(\frac{522}{33} - \frac{1323}{293.25}\right) = 18$ tons, the value assumed.

To illustrate the different strains produced by winding wire at a constant and at a decreasing tension, the following diagrams are given. In the first the *dash* line shows the constant tension of winding (just sufficient to compress the metal of the bore to its elastic limit, 18 tons), the *dotted* line shows the state of strain of the wire after winding, and the full line that under an internal pressure of 27 tons. In the second the *dash* line shows the varying tension of winding, the dotted line the state of strain after winding, and the full line the state of strain under an internal pressure of 27 tons.

It will be seen that in the first case the pressure of 27 tons strains the outer layers of wire beyond the elastic limit of 36 tons, while in the second case no part of the wire passes the limiting tension.

PETROLEUM AS A SOURCE OF EMERGENCY POWER FOR WAR-SHIPS.

By Passed Assistant-Engineer N. B. Clark, U. S. N.

A war-ship requires two different rates of speed: one, for convenience of expression, may be called passage power, which would be used on all ordinary occasions when steaming from port to port; and the other, emergency power, required for chasing an enemy or escaping from a superior force, when a high rate of speed will be necessary.

The requirements of a cruising war-ship, and a commercial vessel making regular passages from port to port, are entirely different. The passenger or fast freight steamer needs sustained high speed to enable her to make trips in the shortest time possible and with the utmost economy of fuel in order to pay a profit to her owners; while the war-ship does not need sustained high speed, but requires a still higher rate of speed to be used only for a few hours at a time in an emergency, it being admissible to attain this extreme high speed at an extravagant cost of fuel, as economy of fuel can only be attained by great weight of machinery, involving increased displacement.

It was the experience of officers who served on the vessels blockading the southern coast that if a blockade-runner was sighted early in the day her capture was almost a certainty, notwithstanding the assumed superiority in speed of that class of vessels; but if the vessel was not sighted in time to admit of her capture before night, darkness frequently enabled her to elude her pursuers, even though they possessed superior speed.

As darkness favors the weak in eluding pursuit, commerce destroyers should be provided with high emergency power to enable them to capture their prizes while daylight lasts.

The passage power of a war-ship should be so designed as to be capable of being used with great economy of fuel, enabling the vessel to steam great distances, and to keep the sea for lengthened periods of time; while on the other hand, to avoid excessive weight of machinery, economy of fuel would be a matter of secondary consideration when using the emergency power, which would be but rarely called into action, and then only for a short period of time, and therefore would not warrant the encumbrance of a great weight of machinery.

The passage power of a war-ship may be sufficient to drive the ship nine or ten knots per hour, while her emergency power should be equal to the attainment of double that speed. This would require the emergency power to approximate to eight times the passage power.

Such enormous power cannot be attained in a vessel of ordinary size, burning solid fuel on grate bars, designed for economy of fuel, unless the entire hull of the ship is filled with boilers, absorbing the greater part of the displacement by the weight of the engines, boilers and fuel, thereby depriving the vessel of offensive and defensive power.

It has been proposed to construct such vessels, in which all other desirable qualities are to be sacrificed to extreme high speed, but the propriety of such a course may well be questioned. High speed alone, without a due complement of defensive and offensive power, would simply enable a naval commander to chase down an enemy which he dare not fight, a feat by which he would gain only negative renown.

Although it is impracticable to construct a vessel of ordinary dimensions, combining extreme high speed with due defensive and offensive qualities, in which the motive power is derived from the combustion of solid fuel on grate

bars, yet, with liquid fuel, such a speed can be developed in a vessel of very moderate displacement.

In boilers for consuming solid fuel the steam generating power is measured by the area of the grate surface, and even when the draught is forced, the amount of heat produced from such fuel is much less than the heating surface will absorb, provided the heating surface is the maximum the boilers will contain.

Solid fuel is burned only from its surface by the erosive action of diluted oxygen, consequently the combustion of such fuel is slow and torpid, compared with liquid fuel, which can be converted into a gas with rapidity and facility.

Ordinary marine boilers for consuming anthracite coal have from 20 to 25 square feet of heating surface to the square foot of grate, and such boilers are found to give good results with solid fuel, as the heating surface is sufficient to absorb all the heat that can be generated from such fuel; but it is possible to construct tubular boilers for burning petroleum having 75 square feet of heating surface to the square foot of grate.

With boilers having the liquid fuel sprayed into their furnaces by jets of superheated steam or hot air, the steam generating power would be measured by the largely increased extent of the heating surface, and not by the limited area of the grate, as the fuel could be consumed at a rate fully up to the capacity of the heating surface to absorb the heat generated by its combustion.

In a properly constructed furnace petroleum can be burned entirely free from smoke, the combustion being complete, and its practical calorific value has been proved to be fully equal to three times its weight of the best coal.

A high authority on engineering subjects, *Molesworth's Pocket-book*, p. 460, revised edition, gives the following account of the method of burning petroleum, as practiced in England, with its advantages as a fuel:

"No alteration of the ordinary furnace or grate is necessary. For burning oil the grate bars are covered with slabs, overlaid with fine cinders, and the ash-pit doors closed. The oil fell vertically, a jet of superheated steam met it, and turned it into vapor, which then took fire and was consumed in a perfect manner.

"The water evaporated amounted to 20.8 pounds per pound of oil consumed. The average result of several days' experiment was 19½ pounds of water evaporated per pound of oil.

"With the best Aberdare coal the same boiler evaporated 6½ pounds of water per pound of coal consumed. The advantages claimed for liquid fuel in seagoing vessels are:

"1st. A reduction of weight of fuel.

"2d. A reduction of bulk of fuel.

"3d. A reduction of fire-room force in the proportion of 4 to 1.

"4th. Prompt kindling of fires.

"5th. The fires can be extinguished instantaneously.

"6th. Capability of stowage in place of water ballast, by which it may be replaced as consumed, and great facility for taking in rapidly.

"7th. Its cleanliness, and freedom from ashes, cinders etc.

"8th. The absence of the loss of heat due to the frequent opening of furnace doors.

"9th. The ability to command a more intense fire, and management of temperature without forced draught.

"10th. Facility for perfect combustion and rapidity of raising steam.

"11th. Freedom from smoke."

Mr. Henry F. Hayden, of Washington, D. C., has recently obtained several United States patents on furnaces for an improved method of burning hydrocarbons, in which the liquid fuel is sprayed into the furnace by a jet of steam superheated to 1200° Fahr., and having the air-supporting combustion heated to 800° Fahr. By this method it is claimed petroleum will give a calorific value greater than the above estimate.

In order to show the merits of petroleum as a source of emergency power we will take for illustration the proposed 3000-ton cruisers, in which it is understood 1200 tons of the displacement is allotted to steam machinery and fuel, the weight of the machinery being 700 tons, and the coal 500 tons.

If the boilers of these ships were specially designed to burn petroleum as an emergency fuel, their steam generating power could be doubled, while their weight could be decreased 150 tons.

The same boilers could also be used to consume anthracite coal with great economy when the ship was using her passage power.

If instead of carrying 500 tons of coal, the ship was equipped with 260 tons of coal, and 80 tons of petroleum stored in the cellular bottom, aggregating 340 tons, she would have her full complement of fuel, the equivalent of 500 tons of coal, thereby effecting a saving in weight of 160 tons.

If this aggregate weight of 310 tons, saved from boilers and fuel, was put into deflecting armor and heavy guns, in addition to the weights already allotted for that purpose, it would produce vessels of moderate size and cost, having a greater emergency speed than any existing commercial vessel, and having offensive and defensive powers equal to a heavy ironclad. Such a ship would combine all the desirable qualities of a light, rapid cruiser, and a heavy coast-defence vessel.

The reason why petroleum has not been used as a fuel in the merchant marine is on account of its cost, and it is not likely that it will ever be able to compete successfully with its powerful rivals, anthracite and bituminous coal.

The objection to the use of petroleum in the vessels of the navy is its assumed dangerous character, but it should be remembered that the same objection could be urged against gunpowder, and was strongly urged against the introduction of steam, notwithstanding which both gunpowder and steam have been introduced, and will be retained in spite of their dangerous character.

In regard to the dangerous qualities of petroleum it may be said, if its storage and use were surrounded by the same safeguards and precautions as those we observe in the storage and use of gunpowder, it would not be found any more dangerous. Besides it should not be forgotten that fighting, the purpose of a war-ship, cannot be made a safe business. The chief danger from petroleum arises from the emanation of an inflammable gas which is given off at all ordinary temperatures, but with refined petroleum this gas is scarcely appreciable in quantity when the fluid is kept at the temperature of sea water, which could be accomplished by storing it in the double bottom of the vessel, and danger from an accumulation of gas in the petroleum tanks could be avoided by providing them with appropriate ventilating pipes, leading overboard, above the water line.

While the cost of petroleum will bar its use as a fuel in the merchant marine, its introduction as an emergency fuel for the navy would be a measure of great economy. In the navy the necessities of the service require a very large fire-room force, fully 33 per cent. of which may be denominated emergency men, whose services might be dispensed with except when the ship is using her full steam power.

With petroleum as a source of emergency power the services of these extra men could be dispensed with, and the cost of their pay, rations, etc., would far more than compensate for the difference between the cost of coal and petroleum, as the pay, rations, etc., of the emergency men would be continuous, while the extra cost of the emergency fuel would only have to be borne for short durations of time at long intervals.

One advantage to be derived from the use of petroleum as a source of emergency power is that it will enable us to retain anthracite coal as the standard fuel of our navy, otherwise we will be forced to use bituminous coal in order to compete in speed with the ships of other nations.

It is proposed to use anthracite coal as the source of the passage power, reserving the petroleum for emergencies, the same boilers serving for each, but

of course the petroleum could be utilized for the lower rate of speed should necessity require it.

Numerous trials of single and twin screw ships of the British navy prove that twin screws utilize 11 per cent. more power in propelling the ship than single screws; this is no doubt due to the greater immersion of the effective area of the twin screws. The principal source of loss with the screw propeller is from skin friction, which is constant at all depths of immersion, while the propulsive efficiency increases with the depth of immersion. As twin screws give an increased efficiency of 11 per cent. over single screws, it is highly probable that triple screws would show a greater efficiency than twin screws, as, owing to the deeper immersion of the shafts, a less area of disk would give an equal propulsive efficiency, and if there was less area of disk there would be less loss from skin friction, and consequently a greater proportionate efficiency from the power applied.

The application of two or more screws would result, not only in a greater economy and efficiency of the power applied, than can be obtained from a single screw, but also in greater safety to the vessel, as it is not probable that all the screws would be disabled at one time. It would also admit of a further decrease of spars and sails, which would be a great encumbrance to a vessel chasing a more lightly sparred adversary, who would not fail to run to windward.

In order to avoid unnecessary friction it would be desirable to disconnect a part of the machinery when using her lower rate of power. This could be accomplished by having the compound engines arranged in two teams, one ahead of the other on the same shaft, with a clutch coupling between the two so that the forward engines could be disconnected and only called into action when the ship was using her emergency power.

Triple screws could then be applied by gearing the outer shafts to the central shaft, from which the entire engine power would be distributed; and if thought advisable in order to give the vessel handiness, a Kunstader steering propeller could be fitted in the rudder.

Ordinary steam machinery of good proportions, as designed for war-ships, with water in boilers and condensers, weighs fully 250 pounds per horse-power; while in the new swift torpedo boats, built on the emergency principle, the steam machinery does not weigh more than 65 pounds per horse-power. This great reduction of weight is accomplished by the adoption of the locomotive tubular boiler, constructed of steel, furnishing steam of high pressure to engines constructed of the very best material, to secure great strength with lightness, designed for extreme high piston speed, whereby great power is transmitted by very light machinery, but at an extravagant cost of fuel; the light machinery developing the great power by its rapidity of movement.

If the same general plan of steam machinery in a modified form was adopted for cruising vessels as that applied in the construction of torpedo boats, engines capable of transmitting the proposed emergency power of 18 or 20 knots per hour could be constructed within the limits of weight allotted for that purpose.

As the torpedo boats referred to, having a displacement of less than 100 tons, have attained a speed of 22.4 knots per hour on the measured mile, the emergency speed proposed will not seem unreasonable for a vessel of 3000 tons displacement to those familiar with the law of speed in relation to dimensions as enunciated by the late Mr. Froude.

Nor would it be necessary to build vessels so large as 3000 tons displacement in order to combine high speed with great defensive and offensive powers, for extremely useful vessels could be constructed on 1500 or 2000 tons displacement, and as a cruiser can only be in one place at a time, no matter how great her size, and as a small vessel upon the plan proposed would be as effective a commerce destroyer as the largest, it would seem to be the best policy to devote the small appropriations obtainable for the increase of the navy to the

construction of a greater number of small ships, rather than to a less number of large ones.

Two such small swift cruisers of 2000 tons displacement, armed with $10\frac{1}{2}''$ pivot guns, mounted on vertical V shields, and with a proper complement of Hotchkiss revolving cannon, having an emergency speed of 18 or 20 knots, and provided with means of discharging rocket torpedoes, would be more than a match for an Inflexible or an Italia, as, owing to their small size and rapidity of movement, they would be very difficult to hit, either with shot or torpedo, while their unwieldy adversary would fall an easy victim to the latter weapon discharged from the two cruisers. The cost of construction and maintenance of one vessel of the Inflexible or Italia class will be found to be much greater than that of two of the proposed cruisers of 2000 tons displacement, while the fighting strength of the two latter combined will be greater than that of one of the former.

THE STEAM ENGINE INDICATOR AS A DETECTOR OF LOST MOTION.

ROBERT GRIMSHAW, M. E.

(*From the Journal of Franklin Institute*, October 1883, p. 245.)

The improved steam engine indicators of the present day, while the legitimate successors of the original and long secret invention of James Watt, in the matter of merely showing the performances in the cylinder and valve-chest and measuring horse-power, are gradually getting a wider application ; and it is to one of their new applications, recently discovered, and not, to my knowledge, heretofore made public, that I desire to call your attention for a few moments,

A very intelligent engineer, Mr. Gilman W. Brown, of Boston, had put in his hands for remedy a most pronounced case of pounding in a high speed engine. This machine thumped at high speeds and at slow speeds ; at high pressures and at low pressures ; at early and late cut-offs, and under apparently all imaginable conditions of lead and compression. Whenever it was attempted to locate the thump, it appeared somewhere else, or at least was not where suspected.

There evidently was only one way to find out where that thump was :—to make it record itself—something which had never before been done, but which was now to be effected.

If the time and the position in the stroke, at which the thump came in, could in some way be graphically recorded, the problem would be a long way towards solution.

Now, if an indicator can pick out the existence and locate the time of lost motion in a valve, why not in that of a crank-pin, or a cross-head pin, or a main bearing ?

It is evident that whatever trace the tell-tale instrument should make of lost motion, outside of the valves, should not interfere with its record of the valve functions ; and the natural deduction was that there must be another trace, necessitating another marking point, in nowise connected with the indicator piston, nor influenced by the steam pressure.

To effect this, there was added to a "Crosby-Brown" indicator a second multiplying lever, having a vertical motion only, and bearing a pencil making a trace underneath and parallel to the atmospheric and vacuum lines of the usual "diagram." This lever was pivoted to a little standard on the connecting piece of the instrument, and the pencil position was adjustable in height by a spring and screw, the latter formed on a light rod passing through the connecting piece. Vertical motion of this rod caused the pencil to vibrate vertically. If the rod was kept at a constant height, the pencil would trace a horizontal line partly around the paper cylinder ; but any pull on the rod would make a jog in the tracing.

The main bearing being slacked up, a vertical metal lever was pivoted to the bed-plate, so as to bear against the far side of the main shaft (assumed to be truly cylindrical, and tested for this purpose beforehand). The upper end of this lever was connected by a wire, or inelastic cord, passing around a guide pulley, to the lower end of the vertical rod on the lost motion lever of the indicator, and all slack taken up and held out by the spring on the vertical rod.

It is evident that if the main shaft has any horizontal movement, it will cause horizontal vibration of the free end of the lever bearing against it, and thus

tighten or slacken the cord and produce a vertical movement of the lost motion lever on the indicator. This will cause a jog, either below or above, in the supplementary horizontal line repressing the cross-head path, and will indicate beyond all question where the lost motion commences, how long it lasts, in which direction it is from the normal, and when and where it stops.

By the aid of this rig, its inventor effectually cured the hitherto incorrigible engine.

BIBLIOGRAPHIC NOTICES.

BULLETIN OF THE AMERICAN IRON AND STEEL ASSOCIATION.

SEPT. 26. New legal standard wire gauge.

The following has been issued by the Standards Department of the British Board of Trade. The new standard gauge has been duly approved by Order in Council, to take effect March 1, 1884.

Descriptive number B. W. G.	Equivalent in parts of an inch.	Descriptive number B. W. G.	Equivalent in parts of an inch.	Descriptive number B. W. G.	Equivalent in parts of an inch.
7/0	0.500	14	0.080	34	0.0092
6/0	.464	15	.072	35	.0084
5/0	.432	16	.064	36	.0076
4/0	.400	17	.056	37	.0068
3/0	.372	18	.048	38	.0060
2/0	.348	19	.040	39	.0052
0	.424	20	.036	40	.0048
1	.300	21	.032	41	.0044
2	.276	22	.028	42	.0040
3	.252	23	.024	43	.0036
4	.232	24	.022	44	.0032
5	.212	25	.020	45	.0028
6	.192	26	.018	46	.0024
7	.176	27	.0164	47	.0020
8	.160	28	.0148	48	.0016
9	.144	29	.0136	49	.0012
10	.128	30	.0124	50	.0010
11	.116	31	.0116	...	....
12	.104	32	.0108	...	....
13	.092	33	.0100	...	....

The following circular has been issued by the same department to the several local authorities under the "Weights and Measures Act, 1878": "After consulting with the various institutions, local authorities, manufacturers, and others practically interested in the use of wire gauges, the Board of Trade have caused a standard measure for wire, etc., to be made and duly verified, which measure has now been approved by Her Majesty in Council, to be, on and after March 1 next, a Board of Trade Standard under the act. I am directed, therefore, by this board to transmit to you a copy of the sizes of this new standard measure, and to ask for the co-operation of your local authority in giving publicity to it in their district, so that by the common adoption in manufacture and trade of a uniform gauge, the annoyance and loss occasioned by the present variety of sizes in use, of which complaint has been made, may no longer arise. I would point out that by the above act it is provided that all measures in use in trade are to agree with the Board of Trade Standards, and that it is the duty of the Inspector of Weights and Measures to see that the act in this respect is carried out."

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

PART IV, 1883. The physical geography and meteorology of the Cape of Good Hope. The tidal constant at Amoy. Solution of the method of double altitudes. Entries at the signal stations for December, 1882. Comparison of the weather of North America and Central Europe for January, 1883. Log notes and meteorological tables.

PART VI. Physical geography and meteorology of the Cape of Good Hope. Determination of the position in the lower latitudes. Report on the tests of chronometers at the Hamburg observatory. Telegraphic determination of longitude in East India, China and Japan.

(This is a summary of the work of Lieutenant-Commanders F. M. Green and C. H. Davis, and of Lieutenant J. A. Norris.)

Commander Bartlett's deep sea researches in the "Blake." Comparison of the weather for March. Brief hydrographic notices and tables.

PART VII. Researches in meteorology and ocean physics in the American-Arctic archipelago by the various English Arctic expeditions from 1819 to 1854. Change in the temperature coefficient of chronometers. Observations on the temperature of the Thames. The third deep sea expedition of the "Travailleur." Hydrographic notes and meteorological tables.

ENGINEER.

JULY 6, 1883. The production of iron by the Siemens direct process from magnetic iron sand.

The catastrophe on the Clyde.

An editorial on the capsizing of the Daphne, a screw steamer of 500 tons, 175 feet long, 25 feet beam and 13½ feet deep. The ship left the ways quite successfully, but she had scarcely moved her own length from the shore when she turned over on her port side and sank in less than three minutes.

JULY 13. Normandy's distiller for torpedo boats.

A compact arrangement of apparatus occupying a space of 40 inches by 22 inches, and of the size generally supplied for torpedo boats, for converting sea water into cold drinking water, and at the same time producing hot fresh water for feeding the boilers, so as to replace that used for distilling purposes.

JULY 20. Certain phenomena manifested by liquid vortex rings. By Mr. Thos. Hart.

An electrical launch.

A handsome launch has been fitted up by Messrs. Yarrow & Co. which has been tried on the Thames with the result of a speed of over 8 knots per hour.

Boilers for the steamship Claremont.

These boilers are designed for the triple cylinder engines of the Claremont, and are to carry a pressure of 150 pounds per square inch. Drawings are given showing the construction.

JULY 27. Church's balanced slide valve.

This slide is of a circular form, held in a loop or buckle on which it is free to turn round, and always in the same direction. This rotation combined with the reciprocating motion gives the valve a gliding moment along the port face, and by continually changing the parts of the surfaces that come in contact with each other, prevents most effectually the formation of hollows or protuberances on the rubbing surfaces.

Examples of the graphic treatment of stresses in framework.

AUGUST 3. On compound locomotive engines.

A paper read before the Institution of Mechanical Engineers by Mr. Francis Webb, showing the advantages obtained by compounding the locomotive engine, and how this may practically be carried out without materially adding to the weight or complicating the working parts.

AUGUST 10. The Edison-Hopkinson dynamo-electric machines.

A report by Mr. Frank S. Sprague shows a remarkable efficiency for this machine, and bears upon experiments which are being made by several firms of electrical engineers, on the relative weight of field magnet cores and poles, and the relation between the weight of wire and iron in field magnets, necessary to give the best results.

The Tower spherical engine. The Edwards gas engine.

AUGUST 17. Submarine mines.

An abstract of General Abbott's report on the physical phenomena accompanying submarine explosions.

The improved Giffard cold air machine.

The action of this machine is to compress the air in a carefully jacketed compression cylinder, and as, however well jacketed the cylinder may be, the compressed air is certain to rise in temperature, after leaving the compression cylinder it is passed through a number of drawn brass tubes, on the outside of which water is circulated by a circulating pump. The air is cooled in this way to within a few degrees of the circulating water, which in the case of machines used on board ship is taken from the sea. The compressed air is then admitted to an expanding cylinder, where it performs work against a piston coupled to the crank shaft, and aiding the compression of the original air. The air when expanded down to about atmospheric pressure is discharged into the freezing chamber and used for any purpose requiring extreme cold. Minus 50 deg. Fah. or 82 deg. below the freezing point is the temperature guaranteed, but this machine has frequently delivered air at a much lower temperature.

Kelway's telemeter.

An instrument designed for the purpose of enabling a navigator to ascertain the distance of his ship from a light, headland or other object without consulting the chart. Continuous bearings can be taken and the mean adopted, so that errors in speed observation are eliminated.

The Nordenfelt gun trials at Dartford.

A series of experiments carried out by Mr. Nordenfelt showing the power of several of his machine guns.

AUGUST 24. An abstract of a paper on the comparison of indicator rigs.

A description of the various methods of attaching the steam engine indi-

cator, with the errors in the diagram consequent upon an incorrect attachment and the manner of correcting the same.

Test trials of a new Whitworth 20-ton gun.

A description of a 20-ton gun, built by Sir Joseph Whitworth & Co. for the Brazilian Government, together with the results of the trial and the behavior of the gun.

Petroleum as a fuel.

An editorial on the efficiency of petroleum as fuel for steam boilers and general heating purposes. One of the alleged advantages in favor of petroleum is that it would occupy much less space than coal, and that ships could therefore take away a much greater supply of fuel, which would enable them to remain longer at sea, and obviate the necessity of coaling depôts. This advantage has been very much overrated, for with petroleum of sp. gr. 0.8, equal spaces would be occupied by equal weights of coal and oil. This allows 50 pounds weight to the cubic foot for coal. It would appear then that taking into account the calorific power of the two fuels, a given amount of storage room would be just twice as efficient if petroleum was used as in the case of coal. In addition to this must be counted the reduction in the number of firemen, which is no doubt an important feature. Against this, however, the highly inflammable nature of the oil must always be considered a source of great danger, as well as the difficulty in storing it in vessels sufficiently away from atmospheric action. There is also the difficulty which may arise from the clogging up of the apparatus and its destruction from the intense heat.

The Daphne disaster.

An able and exhaustive report by Sir Edward Reed on the capsizing of the Daphne in launching, containing some novel and startling disclosures relating to the stability of ships.

Researches on the ignition of mixtures of explosive gases.

AUGUST 31. Experiments on plated forts at Shoeburyness.

Carried out by the Royal Engineers with a view of testing the amount of protection afforded to granite forts by iron plates.

SEPTEMBER 28. Explosions of rockets in Woolwich arsenal. On the resistance of beams when strained beyond the elastic limit.

ENGINEERING.

JULY 13, 1883. Casartelli's high speed indicator.

This instrument presents several novel and interesting features in its construction. The body unscrews midway, the piston is very light. The piston rod is made of steel tube instead of solid steel wire, and is attached to the piston by a universal joint, and to the piston bar in the usual manner. The total weight of the working parts, piston, rod, bar-pencil, etc., is under one ounce. The parallel motion is of the single bar guide type with several modifications, and is jointed at the piston end to long steel levers. The piston rod is mounted directly on the bar, but is screwed and unscrewed the same as in the ordinary Richards instrument.

JULY 20. Dynamo-electric machines driven by Brotherhood engines. Williams patent hydraulic capstan. The story of the battle of Port Said.

An account of a naval battle supposed to be fought in the immediate future.

JULY 27. Models at the Fisheries Exhibition. Borland's lifting injector.

A new form of injector, the principal features of which are its perfect accessibility and small size. By a few turns of a spanner the greater part of the casing can be removed, and the steam nozzle with the whole interior of the injector can be exposed to view; thus all possibility of binding through deposits from the water is prevented. The steam inlet is connected to the body by a union nut, so that it will swivel in any direction, while the overflow is delivered axially from the bottom. The steam and water enter a mixing cone, from this, as is usual, they are projected across a space into a second nozzle, from the lower end of which the stream turns into a delivery pipe. The space around the nozzle communicates with the overflow. The whole of the lower part of the casing, together with the mixing cone, can be removed from the body, as can the upper part with the steam plug and cone, the joints being made metal to metal without packing.

Steam windlass and steering gear.

AUGUST 3. Couplings for broken shafts.

As a means of avoiding the dangers from a broken shaft, Mr. Thompson, superintendent engineer of the Union Steamship Company, has brought out a novel form of coupling. It is made in three segments bolted together, and so designed that while the two end portions obtain a firm grip of the shaft, the middle part is of sufficient diameter to contain a shaft coupling, or the thrust collars, or any jagged or uneven part resulting from the fracture. It is notorious that shafts generally break in most inconvenient places, where it is impossible to apply any hastily constructed coupling, such as can be produced on board ship, but it is claimed for this invention that there is scarcely any form of break which cannot be repaired. Another important use of this coupling is for relieving the strain in any part of a shaft in which a flaw may develop itself while at sea, and hence by its timely employment, dangerous breakdowns may be avoided.

Obach's galvanometers.

These instruments are made in three different types; two of them are suitable for measuring both current strength and electromotive force, whereas the other is for current strength alone.

Burrell's patent governor.

The object aimed at in this design is to take advantage of the effect of centrifugal force alone on the balls, without their being influenced by the action of gravity, and at the same time to produce a powerful, compact and sensitive governor in which there should be no levers or joints liable either to stick or become slack and allow play.

AUGUST 10. Joel's method of laying electrical conductors.

AUGUST 17. Harbors of refuge.

Plans showing the designs of the different schemes proposed for national harbors of refuge.

Boat disengaging gear at the Fisheries Exhibition.

A description of a number of exhibits of disengaging gear, both of the automatic type and the hand gear.

Angle iron bending machine.

A vertical bending machine designed for bending angle iron, T iron and straight bars, as well as wrought-iron manholes for boilers.

The adhesive strength of Portland cement. Experiments on armor plates.

A series of trials carried out by the Danish Admiralty against plates, constructed to represent the deck of a new torpedo boat, were made with the object of ascertaining the resistance of a convex deck, when exposed to horizontal firing, and to determine what kind of armor would be the most advantageous for the new Danish ironclad, which is to be commenced this year.

Penning's pipe joint.

A very ingenious joint for hydraulic mains, steam pipes, etc., consisting of a shallow tapered recess on the ends of the pipes on the inner circumference. Washers of asbestos or rubber are introduced into the recesses. They are of the same form as the recess, except that they do not fill the apex of the V shaped space left by two pipes when placed together. The joint is completed by ordinary flanges and bolts. When this pipe is exposed to internal pressure, the elastic washers will be forced outward against the inclined sides of the recesses and the joint will become tighter with the increase of pressure.

AUGUST 24. The Duncan compound launch engine. The Ferranti dynamo-electric generator.

A description and drawings of a Ferranti machine, designed to supply 5000 lamps, and requiring a current having an electro-motive force of 200 volts, and an intensity of .33 amperes.

SEPTEMBER 7. Machine tools, by Mr. J. Richards. Edison dynamo-electric generator for isolated plants.

SEPTEMBER 14. The Gruson chilled armor plate.

A second series of experiments carried out at Mr. Gruson's works in Buckau, Germany, to test the endurance of a cast-iron shield manufactured on his system.

On geodetical operations, by Mr. G. Pennington. Recent boiler explosions.

Report of inquiries carried out by the Board of Trade on a number of recent boiler explosions.

SEPTEMBER 28. Deep sea sounding and dredging.

Description and sketches of the apparatus used in deep sea sounding and dredging seen at the Fisheries Exhibition.

Stability in naval architecture.

A paper on the use of the term stability in the literature of naval architecture, read before the British Association, by Prof. Osborne Reynolds.

JOURNAL DE LA FLOTTE.

JUNE 3, 1883.

M. Alphonse Milne-Edwards has recently read before the Academy of Sciences, a short notice of the scientific expedition of the *Talisman* in the Atlantic Ocean.

"The Academy has lately expressed to the Minister of the Marine the importance that it attaches to the researches in submarine zoology, and has expressed to him the desire that the explorations made by *Le Travailleur*, in 1880, 1881 and 1882, may be continued. This step has not been unfruitful, and I am happy to announce that the minister has, for this summer, placed at the disposal of a commission of naturalists, of which the presidency has been

given me by the minister of public instruction, a larger and faster vessel than *Le Travailleur*, and has provided it with machines and perfected instruments.

"*Le Talisman* is to start from Rochefort, June 1st, to explore the depths of the Atlantic Ocean. The researches will begin off the coast of Morocco and in the neighborhood of the Canary Isles, and will be continued as far as the Cape Verde archipelago. I intend to study in these places the red coral fishery of San Yago, scarcely known to naturalists, and to explore several desert islands, such as Branco and Raza, on which the great saurians live and to which narrow space the species seems confined, never having been found elsewhere. *Le Talisman* will then proceed to the Sargasso Sea to observe the formation of the bottom, to study the various animals which live in these vast meadows of varec, and thus to collect the materials necessary for the publication of a fauna of the Sargasso Sea.

"Leaving this portion of the Atlantic, we shall visit the Azores, and in September we shall return to France, taking care to mark our route by numerous dredgings. The special care which the minister has taken to provide the vessel with everything that may be useful during this exploring expedition, and the choice that he has made of well-informed, experienced officers, give me hope that this expedition will obtain results even more important than those that have preceded it. If any of my colleagues wish to aid me in special researches, I shall be glad to place at their service the means of work."

JOURNAL FRANKLIN INSTITUTE.

JULY, 1883. Note relating to "water-hammer" in steam pipes.

Prof. Thurston has tested steam pipes which have been burst by this effect, and he finds that the pressures due to this cause may exceed 1000 pounds per square inch. This becomes then a serious matter in the use of long pipes such as will be employed in the underground mains for heating cities by steam. It is evident that it is not safe to calculate upon meeting these tremendous stresses by weight and thickness of metal, but that the engineer must rely upon complete and certain drainage.

Table of piston speeds of marine engines, by Cadet Engineer J. M. Whitham, U. S. N. Liquefaction, vaporization and the kinetic theory of solids and liquids. Abstract of a paper on the comparison of indicator rigs.

OCTOBER. The commercial and dynamic efficiencies of the steam engine, by Prof. Robert H. Thurston. The steam engine indicator as a detector of lost motion (*vide Professional Notes*). Oil-dressed belting. A plea for pure science.

This was the address delivered by Prof. H. A. Rowland, of the Johns Hopkins University, as Vice-President of the Physical Section, A. A. A. S. The style is rather immature. The keynote is struck in the following extract: "American science is a thing of the future, and not of the present or past; and the proper course of one in my position is to consider what must be done to create a science of physics in this country, rather than to call telegraphs, electric lights, and such conveniences by the name of science. I do not wish to underrate the value of all these things: the progress of the world depends on them, and he is to be honored who cultivates them successfully. So also the cook who invents a new and palatable dish for the table benefits the world to a certain degree; yet we do not dignify him by the name of a chemist. And yet it is not an uncommon thing, especially in American newspapers, to have the *applications* of science confounded with pure science; and some obscure American who steals the ideas of some great mind of the past, and enriches himself by the application of the same to domestic uses, is often

lauded above the great originator of the idea, who might have worked out hundreds of such applications, had his mind possessed the necessary element of vulgarity. I have often been asked, which was the more important to the world, pure or applied science? To have the applications of a science, the science itself must exist. Should we stop its progress, and attend only to its applications, we should soon degenerate into a people like the Chinese, who have made no progress for generations, because they have been satisfied with the applications of science, and have never sought for reasons in what they have done. The reasons constitute pure science."

JOURNAL OF THE MILITARY SERVICE INSTITUTION OF THE U. S.

No. XIV. The Military Academy: a discussion of its methods and requirements.

JOURNAL ROYAL UNITED SERVICE INSTITUTION.

No. CXX. The protection of our naval base in the North Pacific.

This paper, by Major-General Laurie, is of the utmost importance to our officers, since it is a detailed consideration of the means which should be taken for the protection of British Columbia on the occasion of a war with this country.

Coaling ships or squadrons on the open sea.

Lieutenant Lowry proposes to transfer the coal from the transport in watertight carriers, which may be taken aboard while the man-of-war and the transport are under way. Drawings of the carriers are given.

Maritime power and its probable employment in war.

PROCEEDINGS INSTITUTION OF MECHANICAL ENGINEERS.

APRIL, 1883. On the strength of shafting when exposed both to torsion and to end thrust.

This is a valuable mathematical paper by Prof. A. G. Greenhill.

MITTHEILUNGEN ÜBER GEGENSTÄNDE DES ARTILLERIE UND GENIE-WESENS.

PART I, 1883. Report of the electrical exhibition at Paris in 1881. Contribution to the integration of the differential equation of the movement of the centre of gravity of projectiles. Freyre's elastic packing for artillery. Blasting coal with lime. Paschwitz telemeter, model of 1882. Products of the Spanish artillery establishments during the year 1880–1881. Technical troops in the larger European states, together with a statement of the bridge and telegraphic material of these corps. The new German torpedo boats. Bursting of a 28 cm. built-up gun in Germany. Explosion of ammunition in Madrid. Submarine torpedo boats.

PARTS II AND III. Description of the new hydraulic crane at the Vienna arsenal, with a power of 75 to 100 tons and a lift of 7 metres. Survey of the fortifications in France, Italy, Russia, Germany, Belgium and Holland. The Lay torpedo for the defence of the Darda-

nelles and the Bosphorus. The Armstrong 100-ton breech-loading guns. New marine guns in Russia. Armor trials at Ochta. Siemens regenerative lamps.

PART IV. Firing tests of the 48 cm. armor at Spezzia. Lighting of mines, powder magazines, etc. Armor trials at Ochta. Influence of the time of felling on the value and durability of wood.

PROCEEDINGS ROYAL ARTILLERY INSTITUTION.

AUGUST 1883. Moving and disappearing targets for rifle practice. Comparative table of English and foreign guns. Experiments with small shot. Problems in gunnery.

This is an application by Major McClintock of Basforth's general tables (as given in his final report) to problems connected with the flight of the rifle bullet and other elongated projectiles.

Memoir of General Sir E. Sabine, F. K. S., K. C. B.

This is an interesting account of the life and work of a gallant officer and an able and industrious man. It contains the following significant sentence: "Like his contemporary, Col. Martin Leake—the one in classical literature, the other in physical science—he gave evidence that a period of most depressing slowness of promotion, and of general stagnation in the atmosphere of Woolwich, could not extinguish the fire of ambition in every breast, or close every avenue *to distinction.*"

TRANSACTIONS AMERICAN SOCIETY OF CIVIL ENGINEERS.

VOL. III, 1882. Determination of heating surface required in ventilating flues. Standard gauge system. Thermodynamics of certain forms of Worthington and other compound pumping engines. Built-up work in engine construction. Expansion of steam and water without transfer of heat. Rankine's theorem on the economy of single-acting expansion engines. The several efficiencies of the steam engine and conditions of maximum economy.

TRANSACTIONS AMERICAN INSTITUTE OF MINING ENGINEERS.

VOL. X. On chimney draught.

Prof. B. W. Frazier treats of the chimney merely as a heat engine, and from this point of view he discusses mathematically the conditions of greatest efficiency.

N. Y. HERALD.

The "circular theory" of storms.

In the British House of Commons, the question was recently put to the president of the Board of Trade, whether it was true that the Meteorological Society had abandoned what was generally known as "the circular theory of storms." Mr. Chamberlain replied that he had no authority to speak for the society, but was informed by its secretary that the members had not abandoned this theory, though recent investigations had shown that some modifications might be suggested. The subject is well worth reopening, and is fully entitled to the prominence given it by this interrogatory in the House of Commons.

The great investigators—Redfield, Reid, and Piddington—who first formulated

the "law of storms," however, never contended that the winds of an ocean storm blow in concentric circles around its centre. As the Nautical Magazine for this month points out, "These founders of the rotatory theory, while they spoke and wrote of circular storms, did so very much in the sense in which meteorologists speak and write in the present day, and they were generally inclined to repudiate as mischievous hard-and-fast rules for the guidance of mariners." Mr. Redfield, toward the close of his investigations, wrote: "I have never been able to conceive that the wind in violent storms moves only in circles," and, "on the contrary, a vortical movement, approaching to that which may be seen in all lesser vortices, aerial or aqueous, appears to be an essential element of their violent and long-continued action." This view was taken by the other early propounders of the so-called circular theory, and has been fully sustained by the latest investigations of marine cyclones.

Père Dechevrens of the Zikawei Observatory, near Shanghai, who has carefully studied the typhoons of the China seas, finds that in the direction of the storm's trajectory, if we suppose its usual direction is that of the lower atmospheric strata, the winds will be divergent in front and convergent in the rear. He also states that the large number of observations received on the passage of typhoons shows beyond doubt that the rule "with your face to the wind the storm centre will be found eight points to the right" is often inexact. In moderately high latitudes and on the inner edge of a cyclone the old rule is, nevertheless, frequently applicable, and seamen should not discard it altogether. In equatorial seas the winds must be more inclined toward the cyclonic centre, and probably are sometimes (especially when and after torrential rains set in near the centre) almost radial.

While no absolute rule can be given by which the seaman can ascertain the exact bearings of the dreaded vortex, these data will enable him to make a valuable approximate calculation of its direction from his ship. If in low latitudes the winds incline sixty degrees, then, as Professor Ferrel points out, the rules based on the strictly circular theory may lead to an error of five or six points of the compass. But such an inclination can hardly be supposed to occur very often. The incurvature of the winds varies in every hurricane in direct proportion to the rapidity with which the barometer falls in the centre, so that it is most likely the endangered mariner, by carefully noting the rate of fall per hour as the yet distant storm approaches his course, may generally discover the direction of the centre and the way to avoid it.

ADDITIONS TO LIBRARY.

Exchanges.

Annalen der Hydrographie u. Maritimen Meteorologie. Nos. 4, 6 and 7, 1883.
Association Parisienne des Propriétaires d'Appareils a Vapeur. Ninth Bulletin.
Bulletin American Iron and Steel Association. Weekly.
Bulletin de la Réunion des Officiers. June 16, No. 24, to Sept. 15, No. 37.
Giornale di Artiglieria e Genio. Part 1, Nos. 3 and 4. Part 2, Nos. 3, 4, 5, 6, 7, 8.
Journal de la Flotte. June 3, No. 22, to Sept. 9, No. 36.
Journal Franklin Institute. July, 1883. Oct. 1883.
Journal Military Service Institution U. S. Nos. 14 and 15.
Journal Royal United Service Institution. No. 70.
Mémoires Société des Ingénieurs Civils. Nos. 1, 3 and 4.
Mittheilungen a. d. Gebiete des Seewesens.
Precis and Translation Royal Artillery Institution. August, 1883.
Proceedings American Philosophical Society. No. 113.
Proceedings Institution Mechanical Engineers. (British.) No. 2, April, 1883.
Proceedings Royal Artillery Institution. August, 1883.
Rivista Marittima. Nos. 6, 7, 8.
Scientific Proceedings Ohio Mechanics Institute. Vol. 2, No. 2.
Transactions American Institute Mining Engineers. Vol. 10.
Transactions American Society Civil Engineers. June, 1883.
Transactions American Society Mechanical Engineers. Vol. 3, and List of Members for 1883.

Donations.

Electricity applied to Explosive Purposes. F. A. Abel. From the Author.
Isherwood's Report on the Siesta. From the Bureau of Steam Engineering.
Korea and Siberia. Lieutenant B. H. Buckingham. From the Office of Naval Intelligence.
Nautische-technisches Wörterbuch der Marine, von P. E. Dabovich. From the Editors of Mittheilungen a. d. Gebiete d. Seewesens.
Report on an Air Refrigerating Machine for Vessels. From the Bureau of Steam Engineering.
Report on the Oyster Beds of James River, and Tangier and Pocomoke Sounds, by Lieutenant Francis Winslow. From the Author.
Soekrigen I America, 1861–1865, by H. J. Müller, Captain Norwegian Navy. From the Author.
Viele Amts Avis, Loverdagen, 22 Nos. From Captain H. J. Müller.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

INTERNATIONAL ELECTRICAL EXHIBITION IN PHILADELPHIA.

To Open Tuesday, September 2d, 1884.

The attention of all persons interested in the generation and application of electricity is respectfully invited to the Exhibition of Electricity and Electrical Appliances to be held in Philadelphia, United States of America, commencing on Tuesday, September 2d, 1884, under the auspices of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

From the eminent reputation of this institution, coupled with the fact that the projected exhibition will be the first in America exclusively devoted to this important and progressing branch of science, the above announcement has attracted unusual interest throughout the United States, and the exhibition will undoubtedly afford an admirable opportunity of witnessing a representative display of American discovery and invention in electricity.

To increase its scientific and industrial importance, as well as to add to its attractiveness, it was determined shortly after its conception to give it an international character. The importance of the project having been properly represented to the Congress of the United States, an act was passed which, having received the signature of the President of the United States, is now the law.

The official recognition provides for the admission into the United States, duty free, of all articles for exhibition only. The text of this act of Congress is as ollows:

"Whereas, the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts proposes to hold an exhibition of electrical apparatus, machinery, tools and implements, and other articles used in scientific and mechanical and manufacturing business and investigations; and

"Whereas, it is deemed desirable to promote the success of such an exhibition by all reasonable encouragement, in order that it may be made useful for the promotion of knowledge; therefore, be it

"*Resolved*, by the Senate and House of Representatives of the United States of America, in Congress assembled, that all articles that shall be imported for the sole purpose of exhibition at the Exhibition to be held by the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, in the city of Philadelphia, in the years 1883 or 1884, shall be admitted without payment of duty or customs fees or charges, under such regulations as the Secretary of the Treasury shall prescribe; *provided*, that all such articles as shall be sold in the United States, or withdrawn for consumption therein at any time after such importation, shall be subject to the duties, if any, imposed on like articles by the revenue laws in force at the date of importation; *and provided, further*, that in case any article imported under the provisions of this joint resolution shall be withdrawn for consumption, or shall be sold without payment of duty as required by law, all the penalties prescribed by the revenue laws shall be applied and enforced against such articles, and against the persons who may be guilty of such withdrawals or sales."

It remains only to add, at the present time, that no effort will be spared by the Franklin Institute to secure a large and important representation of the progress of foreign countries, and that the most liberal provisions will be made to place European and American exhibitors on a fair and equal footing.

The subject of electricity and its applications is at present attracting an unusual amount of attention, and the exhibition side by side of the best achievements of Europe and America cannot fail to be in the highest degree instructive.

All information required by exhibitors, including the classification of exhibits, regulations for the entry of articles for competition, advices as to the best modes of transportation, custom house regulations, and all other needful information, will be furnished to parties making application for space for exhibition.

Such applications should be made to the Secretary, Franklin Institute, Philadelphia, U. S. A.

For the Franklin Institute:

William P. Tatham, *President.*
William H. Wahl, *Secretary.*